FACULTY OF PSYCHOLOGY
AND EDUCATIONAL SCIENCES

Depression, rumination, and information processing: A cognitive-motivational analysis

Lin Fang

Supervisor: Prof. Dr. Ernst H.W. Koster

A dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Doctor of Psychology

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CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

Depression is one of the most prevalent of all psychiatric disorders (Kessler et al., 2005). Epidemiological surveys have shown that approximately one out of five individuals in the general population have at least one episode of depression during their life (Gotlib & Hamilton, 2008). Depression has also been found to commonly co-occur with other mental diseases. For example, it appears frequently to show comorbidity with anxiety disorders (Gorman, 1996; Swendsen, 1997), PTSD (Bleich, Kosllowsky, Dolev, & Lerer, 1997; Stein & Kennedy, 2001) and personality disorders (Fava et al., 1996; Robert & Hirschfeld, 1999). A substantial number of surveys and studies have shown that depression is related to poor work performance (Kessler et al., 2006; Wang et al., 2004), impaired social skills (Segrin, 2000; Tse & Bond, 2004), reduced social interaction and social support (Cruwys et al., 2013; Fukukawa et al., 2004; Rauktis, Koeske, & Tereshko, 1995), and increased suicidal ideation and attempts (Carpenter, Hasin, Allison, & Faith, 2000; Evans, Hawton, & Rodham, 2004; Harrington, 2001). The overwhelming personal suffering and huge economic cost of depression in society has raised public concern regarding depression and its treatment (Andrews, Poulton, & Skoog, 2005; Kessler et al., 2010).

Despite the availability of a wide variety of treatment options, such as pharmacotherapy, psychotherapy, and neurobiological interventions, the relapse and recurrence rate remains high in depression (Beshai, Dobson, Bockting, & Quigley, 2011; Demyttenaere et al., 2004; Steinert, Hofmann, Kruse, & Leichsenring, 2014). In people who have remitted from depression, the risk of relapse is about 50% after a first episode, 70% after two episodes, and 90% after a third episode (for a review, see Burcusa & Iacono, 2007; Gili, Vicens, Roca, Andersen, & McMillan, 2015; Kessler et al., 1996). Unfortunately, approximately 10%-20% of depressed patients show no response to any treatment (Burrows, Norman, & Judd, 1994; Holtzheimer & Mayberg, 2011).

These findings suggest that latent risk factors may still exist when depressive patients are in a remission period which may then exert a disruptive influence on wellbeing when triggered by stressful life events (for a review, see Joormann & Tanovic, 2015). Therefore, discovering the factors that make people vulnerable to depression should be considered highly important in the study of depression and its treatment.

Rumination is of particular interest to researchers focusing on vulnerability to depression. Decades of research have shown that rumination is one of the most important risk factors for the onset and maintenance of depressive symptoms (Mor & Winquist, 2002; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Two main issues have received considerable attention over the past two decades. First, what kind of people tend to ruminate more often than others, and second, how people who ruminate get trapped in the vicious circle of rumination. Several theoretical frameworks have been proposed and a large body of research has accumulated concerning these two questions. In this chapter, we first introduce a definition of depressive rumination, which is the definition used throughout the whole dissertation. To provide background to the first question, we briefly summarize the measures and manipulations of rumination in laboratory studies. Subsequently, we describe several vital cognitive frameworks on information processing in rumination and related empirical studies testing the predictions of these models. A comprehensive answer to the second question requires not only laboratory studies but also daily life experience. To obtain real-life data, experience sampling method has been applied in previous studies. Thus, the basic procedure of experience sampling method is provided and the findings concerning daily ruminative thinking are reviewed. Next, dynamic system theory is introduced as a powerful framework to analyse and interpret experience sampling data. Basic concepts of dynamic system theory used in the following chapters are elaborated. Finally, the main research questions and corresponding research lines of this thesis are presented.

DEPRESSIVE RUMINATION

In general, rumination is characterized as repetitive self-focused thinking (Watkins, 2004, 2008). Most conceptual work on rumination has emerged in the context of depression. Based on the response styles theory, rumination is conceived as a form of responding to negative mood that focuses in a perseverative and repetitive manner on the implications, causes, and meanings of one's feelings and problems (Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008). It has been repeatedly observed that depressive rumination has detrimental effects on mood, problem-solving, and cognitive processes (Watkins, 2008). Depressive rumination has been demonstrated to prospectively predict the onset and maintenance of depression (Just & Alloy, 1997; Kuehner & Weber, 1999; Nolen-Hoeksema & Morrow, 1993). It has also been found to be a mediator between other risk factors and depressive symptoms (Spasojevic & Alloy, 2001). Hence, understanding the underlying mechanism of rumination and its relation with depression may provide insight to prevention, intervention, and treatment of depression.

Most laboratory studies in rumination assess rumination with self-report questionnaires. Corresponding to the definition of depressive rumination, Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991) has been developed as a common measure of the tendency to ruminate in response to depressed mood (Davis & Nolen-Hoeksema, 2000; Nolen-Hoeksema et al., 2008). Generally, individuals are asked to rate items on a 4-point scale of the 22-item RRS while thinking about how they typically respond when they are in negative or depressed mood. Previous studies using the RRS have shown that trait rumination is a relatively stable construct across different contexts (e.g., across different mood states and levels of depression) (Bagby, Rector, Bacchiochi, & McBride, 2003; Nolen-Hoeksema, Parker, & Larson, 1994; Nolen-Hoeksema & Davis, 1999). There are also other questionnaires that target different features of rumination, such as the Global Rumination Scale (McIntosh & Martin, 1992), and the Anger Rumination Scale (ARS; Sukhodolsky, Golub, & Cromwell, 2001) amongst others (for a review, see Watkins, 2008; Whitmer & Gotlib, 2013).

Importantly, several researchers proposed a distinction between two subtypes of rumination, which are constructed and termed as brooding and reflection in the RRS subscales (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Reflection involves thoughts that are more oriented towards reappraisal that leads to engagement in problem

solving (Gibb, Grassia, Stone, Uhrlass, & McGeary, 2012; Schoofs, Hermans, & Raes, 2010). While reflection has been related to a relatively less detrimental aspect of rumination, brooding has been considered as a more maladaptive form of rumination (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Nolen-Hoeksema et al., 2008; Treynor et al., 2003). Brooding refers to a passive, abstract self-focus on one's mood by comparing one's current situation with unattained goals. It has been shown to be associated with the onset and maintenance of depressive episodes (Nolen-Hoeksema, 2000; Nolen-Hoeksema, Morrow, & Fredrickson, 1993), emotional inertia (Koval, Kuppens, Allen, & Sheeber, 2012), and attentional bias to negative information (Owens & Gibb, 2016; Vanderhasselt et al., 2013).

In addition to assessment of trait rumination with self-report questionnaires, many laboratory studies also tried to activate state rumination using induction procedures in order to investigate its influence on cognitive functioning (Whitmer & Gotlib, 2013). For example, some researchers asked participants to read a series statements (e.g., "Think about why you react the way you do") which required them to focus on themselves and vividly think about how they feel (Lyubomirsky & Nolen-Hoeksema, 1995; Nolen-Hoeksema & Morrow, 1993; Watkins & Teasdale, 2001). Other researchers also created some scenarios and asked participants to think about the situation in a ruminative manner (e.g., "think about what consequences this has for how you see yourself") (Grol, Hertel, Koster, & De Raedt, 2015). Before and after the induction procedure, participants' state rumination was measured and then compared to assess the effect of the induction. Previous studies have shown that state rumination may be associated with cognitive deficits, such as increased levels of cognitive distortions (Watkins & Teasdale, 2001) and decreased inhibition ability in dysphoric participants (Philippot & Brutoux, 2008), as well as enhanced processing of negative information (Lewis, Taubitz, Duke, Steuer, & Larson, 2015) and lower mood (Huffziger et al., 2013) in non-selected undergraduate samples. Importantly, several researchers found that rumination induction did not influence switch costs in healthy controls (Whitmer & Gotlib, 2012). It is still not clear whether these results were because that healthy individual may be less reactive to rumination induction or that state rumination does not deteriorate the corresponding cognitive functioning.

In sum, great effort has been made in describing, measuring, differentiating, and inducing different types or aspects of rumination. Despite the large body of research concerning levels of rumination and its impact on depression, research interest has shifted to the question why rumination persists (Watkins, 2008). Especially in the last ten years, researchers tried to identify cognitive factors that contribute to the persistence of ruminative thinking. Below, we review the most recently developed theoretical frameworks that reveal the underlying cognitive mechanism of rumination.

INFORMATION PROCESSING OF RUMINATION: COGNITIVE ACCOUNTS FOR THE MECHANISM OF RUMINATION

In a large number of studies with regard to the information processing in rumination ranging from cross-sectional to longitudinal designs, the function of cognitive control has received wide attention (Vergara-Lopez, Lopez-Vergara, & Roberts, 2016). This has led to the development of a number of theoretical models. Early suggestions that inhibition is important in the persistence of depressive rumination derived from propositions of Joormann (2010). From the account of the impaired disengagement hypothesis (Koster, De Lissnyder, Derakhshan, & De Raedt, 2011), rumination may be accounted for by difficulty in disengagement of attention from the activated thoughts in working memory. Further, attentional scope has been argued to be one of the most important cognitive factors that influence the repetitive feature of rumination (Whitmer & Gotlib, 2013). Finally, researchers also have also developed a goal habit framework of rumination (Koster et al., 2011; Watkins & Nolen-Hoeksema, 2014). These models are discussed in the next section.

Cognitive inhibition and rumination

The propositions provided by Joormann (2010) have emphasized the role of cognitive inhibition in emotion regulation. Joormann suggests that deficits in inhibition of negative information in working memory may cause increases in rumination. In

specific, when individuals experience negative feelings, mood-congruent negative schema, which refers to internal representations of concepts about oneself and the world (Beck, 1967, 1995), tends to be easily activated. Normally, individuals would make an effort to replace the dominant negative thoughts from working memory with some other thoughts that are more positive to reappraise the current situation. However, individuals with impaired cognitive control, especially in inhibition, would have trouble removing the activated negative thoughts and keeping new negative information from entering working memory. This would lead to detrimental consequences in emotion regulation, such as increased usage of rumination and decreased usage of reappraisal.

Quite substantial empirical evidence supports the notion of a relation between rumination and inhibition (for a review, see Cohen, Daches, Mor, & Henik, 2014; Monnart, Kornreich, Verbanck, & Campanella, 2016). Notably, by comparing dysphoric individuals and healthy controls, some researchers have suggested that inhibition difficulties were associated specifically with rumination but not with depression in general (De Lissnyder, Koster, Deraksha, & De Raedt, 2010). Other researchers found that impaired inhibition of negative words was associated with rumination and depression only in currently depressed patients but not in remitted depressed patients and healthy controls (Joormann & Gotlib, 2010). Furthermore, most of the previous studies only examined the association between cognitive inhibition and rumination in cross-sectional designs while scant attention has been paid to their causal direction (Cohen et al., 2014; Roberts, Watkins, & Wills, in press). Few studies examined whether inducing participants to ruminate has an impact on inhibition (Philippot & Brutoux, 2008) and in turn, whether training the ability to inhibit negative information in trait ruminators could decrease their rumination level (Daches & Mor, 2014). More research is needed to extend and elaborate this hypothesis.

The impaired disengagement hypothesis

In 2011, Koster and colleagues have put forward the impaired disengagement hypothesis to unravel the underlying mechanism of rumination. They stated that rumination at the beginning is one of the forms of emotion regulation elicited by

negative mood or stressors in life, and therefore, is not necessarily a maladaptive regulation strategy. It is the persistent use of rumination that is associated with impaired problem solving, negative emotions and the development of depression. With regard to how individuals get stuck in sustained rumination, the main assumption of this hypothesis points out that difficulties in disengaging attention from negative self-related thoughts may be the underpinning mechanism. They delineated the possible processes that could be involved in attentional disengagement. Specifically, when individuals are in negative mood, this is usually accompanied by increased self-critical thinking. Such thoughts can elicit cognitive conflict between self-critical thinking and typical positive self-evaluation. The awareness of this conflict may elicit an effort to move attention away from the current negative thinking which would help re-evaluate the current situation or engage in a different new task. Difficulties to disengage attention could happen at any of the abovementioned processes in the whole attentional disengagement procedure. If there is problem in the conflict detecting, such as people have low or negative self- schema, then less arising conflict would lead to less motivation to change their current attentional focus. General attentional control, such as updating, inhibition and set shifting, may cause the impairment when individuals attempt to remove the current negative thoughts and process new information.

The impaired disengagement hypothesis could be used to explain findings of various studies concerning the relation between rumination and cognitive control especially in individuals with heightened levels of depressive symptoms. It has also received empirical support. For example, a recent study conducted an attentional assessment task in undergraduates, which contains attentional engagement bias assessment trials and attentional disengagement bias assessment trials to detect which process is involved in relation to heightened trait rumination (Grafton, Southworth, Watkins, & MacLeod, 2016). Their findings provided evidence for the impaired disengagement hypothesis in that high trait rumination was associated with deficits in attentional disengagement from negative information but not with facilitated attentional engagement to negative information. Additionally, they also found that relative to anxiety-related words, attentional bias to depression-related words was positively correlated with trait rumination scores, which was consistent with the proposition of the impaired disengagement hypothesis that depressive rumination is

characterized by specific attentional bias for negative/ depressogenic information. Similar results were found in a related study which revealed that higher levels of brooding were related to greater difficulties to disengage attention from negative relative to positive words (Southworth, Grafton, MacLeod, & Watkins, 2017). Using the same attentional assessment task, in a study on undergraduate psychological students preparing for mid-term exams, researchers found that rumination was associated with impaired disengagement of attention from negative words, and that this bias mediated the predictive effect of rumination on stress reactivity (Vålenas et al., 2017). In addition, previous studies also showed association between rumination and impaired cognitive control for negative stimuli (Chen, Feng, Wang, Su, & Zhang, 2016; De Lissnyder et al., 2012a, 2012b; Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Hilt, Leitzke, & Pollak, 2016; Koster, De Lissnyder, & De Raedt, 2013; Yoon, LeMoult, Hamedani, & McCabe, 2017).

Despite having been supported by a wealth of well-replicated findings, some of the propositions of the impaired disengagement hypothesis still need to be considered cautiously. For example, several studies examined associations between rumination and cognitive control using both positive and negative stimuli. They found that, contrary to the valence-specific prediction of the impaired disengagement hypothesis, cognitive control difficulties were not only connected with negative information, but also appeared when positive materials were presented (Joormann, 2006; Joormann & Tran, 2009; LeMoult, Arditte, D'Avanzato, & Joormann, 2013). These findings suggest that the cognitive control deficit may not be valence-specific. It is also possible that there are other underlying cognitive factors that could influence the perseverance of rumination across a broad range of information.

The attentional scope model of rumination

Whitmer and Gotlib (2013) have developed a model called the attentional scope model of rumination which posits that attentional scope could be a critical factor that affects the repetitive nature of thinking in rumination. It states that the effect of mood on rumination may actually be mediated by attentional scope. Moreover, it tries to explain the primary source of individual differences that makes some individuals

ruminate more than others when encountering sad situations. It assumes that individuals with a narrow attentional scope would engage in rumination more often than do individuals with broad attentional scope when they are in a negative mood. Specifically, it argues that, when in a neutral mood, individuals who have a narrow attentional scope will show a greater tendency to constrain most of their attentional resources to a limited set of focal thoughts. Then when they feel distress, negative mood will further narrow attentional scope and, as a result, magnify focusing on a single set of thoughts concerning negative mood or problems. In contrast, individuals with a broad attentional scope would allocate their attentional resources to a relatively large range of information. When they feel sad, although the negative emotions narrow their attentional scope as well, their broader attentional scope would make them less susceptible to the narrowing effect of negative emotion.

According to the basic assumption of this model, it could be postulated that trait ruminators have a narrower attentional scope than non-ruminators, even in a neutral mood state. Indeed, previous studies have shown that higher levels of trait rumination were associated with problems in inhibiting prior relevant information (Whitmer & Banich, 2007; Whitmer & Gotlib, 2012), decreased intentional forgetting both positive and negative information (Joormann & Tran, 2009), and better performance on a flanker task (Zetsche & Joormann, 2011). Whitmer and Gotlib (2013) argued that difficulties in inhibiting no-longer relevant information and less influence by distractors are typical features of having a narrow attentional scope. When performing tasks with a narrow attentional scope, individuals invest the majority of their attentional resources towards task relevant information. This way of allocating attention may result in other task irrelevant information gaining less access into working memory which would improve the ability to thoroughly process relevant material and ignore distraction. The high intensity and amount of attentional resources on the current task relevant information, however, may reduce the chance that new information gains access or becomes prevailing in working memory.

Although the attentional scope model of rumination provides an alternative explanation for a large number of previous findings in perception, working memory and long term memory (for a review, see Whitmer & Gotlib, 2013), until now relatively little research has directly examined this model. In a recent study trying to investigate the

influence of rumination on attentional scope (Grol et al., 2015), healthy undergraduates were first assessed on their trait rumination score and then randomly assigned either to a rumination or a problem-solving induction. After the 10 minute induction procedure, participants' visuospatial attentional scope towards self- or other-related information was examined. The findings showed that participants with a higher level of trait rumination who underwent the state rumination induction showed a more narrow attentional scope for self-related information relative to other-related information. In their second experiment (Grol et al., 2015), they explored the relationship between trait rumination and attentional scope without manipulation of state rumination. They found that higher levels of brooding, which is the more depression related sub-component of trait rumination, was associated to a more narrow attentional scope for self-related information relative to other-related information. These findings suggest that rumination is associated with a narrowed attentional scope in visual attention, especially when confronted with self-related information. In addition, in a study exploring the relation between cognitive inhibition and emotion regulation, researchers found that the positive correlation between reappraisal and the ability of inhibiting negative words was only present in people with low levels of brooding but not in those with high levels of brooding (Daches & Mor, 2015).

Rumination as a mental habit

Some models not only concentrate on the individual differences in cognitive factors that contribute to rumination (e.g., the ability of disengagement or attentional scope), but also try to explain how rumination becomes a maladaptive emotion regulation habit upon the interaction between (state) rumination and environment. For example, the impaired disengagement hypothesis (Koster et al., 2011) contended that sustained rumination can lead to impaired problem solving and prolonged negative emotions which in turn increase the usage of rumination. The repetitive occurrence of this reciprocal interaction between rumination and its consequences initiates a vicious cycle through which rumination turns into a habit.

Recently, a habit goal framework of depressive rumination, provided by Watkins and Nolen-Hoeksema (2014), conceives of rumination as a mental habit and tries to

characterize how state ruminative thinking develops into a habitual thinking style. In combination of response styles theory (Nolen-Hoeksema, 1991) and control theory (Martin & Tesser, 1996), this framework proposes that some people start to ruminate when they realize there is discrepancy, which always appears together with negative feelings, between their current status and their major goals. If state rumination occurs frequently enough as response to the same negative discrepancy context, it will become a habitual response that could be cued automatically by the context. After a certain period of time, habitual rumination can be activated by a negative context without the involvement of goals. As long as rumination becomes a habitual response to negative context independent of goals, it is hard to change it, even when the current goal has been achieved or altered.

Summary

The above mentioned theoretical accounts of rumination share a common concern in explaining the repetitive nature of rumination. They all assume that it is the difficulty of removing previous task-related thoughts from working memory that leads to the persistence of rumination. However, they propose different mechanisms that determine the difficulty of updating working memory in rumination. Whereas cognitive inhibition is considered as the main reason why individuals have difficulties to get rid of negative thoughts (Joormann, 2010), it might only be one of the components in general cognitive control that influence one of the steps of the disengagement of attention in working memory (Koster et al., 2011). The attentional scope model of rumination, on the other hand, does not stress the role of impaired cognitive control in negative or depressed information, but argues that rumination is related to individual differences in general (i.e., attentional scope), and thus is not necessarily an impaired way of information processing. Therefore, it can provide an explanation for findings showing that levels of rumination influence the processing of not only negative materials but a broad range of information (Joormann, 2006; Joormann & Tran, 2009; LeMoult et al., 2013).

Interestingly, while previous views highlight the disadvantages of impaired cognitive control in rumination, the attentional scope model of rumination describes

the problematic as well as beneficial effect of the way how high ruminators allocate their attention on different tasks. For example, people with a narrow attentional scope would constrain their attention onto current task-relevant information so that they can deeply encode task-related information. This may reduce the chance of new information gaining access into working memory which would then lead to perseverance of a limited amount of information. But this focused attention can also facilitate prevention of the interference caused by irrelevant distractors. Indeed, previous studies have shown that trait ruminators had better performance in tasks that need people to maintain their attentional focus in task-relevant information (Altamirano, Miyake, & Whitmer, 2010; Zetsche & Joormann, 2011). Taken together, the attentional scope model of rumination seems to have a potential to explain previous contradicting findings by providing a more complex way to understanding the attentional control mechanism of rumination. However, until now, few empirical studies have directly tested the assumptions of this model (e.g., Grol et al., 2015). In Chapter 2-4 of this dissertation, a series of studies were conducted to examine the main predictions of this model. Specifically, the relation between attentional scope and rumination was inspected at perceptual level.

Moreover, in line with the propositions that narrow attentional scope of high ruminators may help improve performance in certain tasks, occasional rumination as an emotion regulation strategy is not necessarily maladaptive as well. It is habitual rumination, which people often passively use when they feel depressed without taking into account specific requirements of the current context, which makes them vulnerable to depression. Notably, it takes a long time for state ruminative thinking to become a relative stable and automatic habit. Once the habit emerges, it may be resistant to change. Corresponding treatment and intervention are expected to be more effective if they could be carried out before the formation of habitual rumination. For this reason, it is crucial to investigate how state-like ruminative thinking changes and interacts with its cognitive and affective consequences in daily life. To do this, studying real-life experiences may be necessary. Of further interest is whether daily patterns of rumination, i.e. reciprocal interactions between rumination and affect in daily life, predict future depressive symptoms.

EXPERIENCE SAMPLING METHOD

Given the dynamic nature of thoughts and emotions, it is necessary to probe and record their changes with multiple measurements (Myin-Germeys et al., 2009). The changes over time can be measured accordingly through experience sampling methods (Kircanski, Thompson, Sorenson, Sherdell, & Gotlib, 2015). Experience sampling method (ESM) is a structured self-report measurement in which individuals are typically required to answer a certain number of questions several times a day across several days (Myin-Germeys et al., 2009). Decades of research have demonstrated that ESM is a valid and reliable technique that is assumed to be sensitive to behavioural and emotional changes in daily life (Myin-Germeys et al., 2009; Csikszentmihalyi & Larson, 1987). For instance, ESM has been found being able to catch subtle temporal changes that can hardly be detected when using trait measurement (Palmier-Claus et al., 2010).

In the domain of emotion regulation, participants have always been asked to evaluate their momentary affect/emotion, emotion regulation strategy, and related context such as stressful events either at the time when they receive signals from researchers or during the period between the last and the current signal. Unlike trait-like rumination, such as the one measured by RRS (Nolen-Hoeksema & Davis, 1999), ruminative thought in daily life is an ongoing dynamic process (Kasch, Klein, & Lara, 2001) and thus can be measured accordingly through the ESM (Kircanski et al., 2015; Moberly & Watkins, 2008). In the first study concerning the relation between momentary rumination and affect (Moberly & Watkins, 2008), an unselected sample of individuals was instructed to assess their momentary rumination and affect 8 times a day for 7 days. Two items were created to measure momentary ruminative thinking (“focused on feelings” and “focused on problems”) which have been widely adopted in later ESM studies. They also used three items to measure negative affect (“sadness”, “anxiety”, and “irritation”). This study was the first to show that momentary ruminative thinking reciprocally interacts with negative affect. Following this study, a large number of studies have been concentrating on momentary rumination and affect, trying to observe and describe their daily patterns, their interaction and their association with future depressive symptoms.

Previous ESM research has shown that momentary rumination is often followed by exacerbation of negative affect (Hoorelbeke, Koster, Demeyer, Loeys, & Vanderhasselt, 2016; Kircanski, Thompson, Sorenson, Sherdell, & Gotlib, 2017; Moberly & Watkins, 2008; Takano & Tanno, 2011) and/or decreases in positive affect (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Hoorelbeke et al., 2016; Huffziger et al., 2013; Kircanski et al., 2017). In turn, affect also influences rumination. For example, negative affect has been found to predict subsequent rumination, which suggests a reciprocal relation between momentary rumination and affect (Hoorelbeke et al., 2016; Moberly & Watkins, 2008). Particular interest has arisen in differentiating contributions of momentary emotion regulation, momentary affect, and their link to the development of depressive symptoms. Previous findings revealed that future depressive symptoms could be prospectively predicted by momentary rumination in the evening relative to in the morning (Takano & Tanno, 2011), momentary rumination and emotional inertia (Koval et al., 2012), the average levels of momentary rumination but not its impact on emotions (Pasyugina, Koval, De Leersnyder, Mesquita, & Kuppens, 2015), and the beliefs about worry and rumination (Hartley, Haddock, Vasconselos e Sa, Emsley, & Barrowclough, 2014). Interestingly, a study also found that depressive symptoms can moderate the relation between daily activities and momentary rumination where people with higher levels of depression use less ruminative thinking when they engage in pleasant activities (Takano, Sakamoto, & Tanno, 2013).

Recently, some studies combined measurements of cognitive control in lab and measurements of momentary rumination in daily life. For example, in a study conducted in first-year undergraduates that sought to examine whether individual differences in cognitive control could moderate the influence of emotion regulation on affective experiences (Pe et al., 2013), the impairment of cognitive control was assessed by an affective interference resolution task at baseline. After that, momentary assessment was conducted for 10 times a day within 7 consecutive days in which positive and negative affect were assessed with 6 items whereas rumination and appraisal were measured by one item each. There were also 4 items targeting additional emotion regulation strategy. The results showed a moderation effect of negative interference level on the impact of emotion regulation on affect in daily life. Specifically, greater increase of negative affect was found when using rumination in

individuals with high impairment in removing no-longer-relevant negative information from working memory. Another study measured momentary brooding in high trait ruminators after 10 days of intensive cognitive control training (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015). They found, in a four-week follow-up, that individuals in the cognitive control training group showed decreased levels of brooding when facing naturalistic stressor in daily life.

In sum, the ESM has provided us a chance to closely inspect the fluctuations of our emotions and emotion regulation on a daily basis. However, to better understand ESM data and, indirectly, the underlying emotion regulation processes, researchers need to find appropriate tools. The knowledge of how momentary ruminative thinking and emotion influence each other and what underlying mechanism might generate and affect the changing data sequence can be improved if the underlying dynamic process is understood.

DYNAMIC SYSTEMS APPROACH FOR INVESTIGATING RUMINATION IN DAILY LIFE

There are multiple ways in which fluctuations of rumination in daily life can be conceptualized and investigated. What is lacking, however, is a well-established and systematic conceptual framework that may precisely capture and describe the temporal and probably non-linear features of this fluctuation (Smith & Alloy, 2009). Regarding the continuous changing nature of daily ruminative thinking, dynamic system theory may be a powerful and appropriate method (Koster, Fang, & Marchetti, 2015). Dynamic system theory has been used in various disciplines, such as physics, biology, psychology and geography and so on. In the following paragraphs, basic concepts in dynamic system theory are briefly introduced.

Dynamic systems

Dynamic systems theory (DST) provides principles and a useful framework to examine how systems containing multiple variables change over time (Hollenstein, 2013). A system can be conceived as a set with different components. A dynamic system is a system with different components that change over time (Lewis & Granic,

2000; Thelen & Smith, 1998). If we consider human beings as a dynamic system, then behaviour, thoughts, and emotion are key components of this dynamic system. According to DST, a dynamic system is posited to unfold over time in a non-linear way, in which each component interacts with the others and forms the behaviour of the whole system (Sulis & Trofimova, 2001). Further, it proposes that unique features emerge during reciprocal interaction among different components, which suggests that the whole system itself shows features that are absent or non-detectable at the level of components that make up the system (Guastello, Koopmans, & Pincus, 2008). Given these features, DST might be useful to model in real time the complex interaction between emotion and emotion regulation, such as momentary affect and ruminative thinking. The questions about how ruminative thinking and affect interact with each other and how their interactions or co-occurrence play different roles in the development of depressive symptoms may be elucidated by applying a dynamic systems approach.

It has been proposed that a dynamic system is hierarchical with different levels of components, such as micro-level and macro-level, interacting with each other (Hollenstien, Lichtwarck-Aschoff, & Potworowski, 2013; Wichers, 2013). Components at micro-level can build or form a new component at macro-level after a certain amount of time whereas this new higher level component can then influence or constrain the change of those ones at micro-level (Wichers, 2013). As mentioned before, there is an increasing interest in investigating micro-level daily changes, such as momentary ruminative thinking. Consistent with DST, it would be interesting to look at the development of rumination in this hierarchical dynamic system. Thus, the habit shaping process can be conceptualised as follows: ruminative thinking at micro-level interacts with a certain context in the beginning. After a certain amount of time, habitual rumination (i.e., trait rumination) emerges at the macro-level. Habitual rumination at the macro-level then constrains the usage of ruminative thinking at the micro-level, such as increasing the co-occurrence of ruminative thinking with negative affect. Accordingly, it would be informative to examine whether momentary rumination and affect at the micro-level have a predictive impact on depressive symptoms and rumination at the macro-level. In turn, it would also be interesting to investigate

whether rumination at the macro-level has an impact on momentary rumination at the micro-level.

State space, attractor, and entropy

To illustrate the abstract changes of behaviour and emotion in real time, *state space* has been developed in the DST domain. State space is a conceptual space where all possible states of a system are represented (Shelhamer, 2007). A system can only be in one state at one time and mostly some predominant states will be revisited more often than others under certain circumstances (Carver & Scheier, 1998; Lunkenheimer, Hollenstein, Wang, & Shields, 2012). These recurring states are called *attractors* in DST (Thelen & Smith, 1998). When one or few states have relatively strong strength, a system may stay in a relative stable mode. Even if there is a disturbance in the system, strong attractor states may constrain the duration and range of the fluctuation of the system. It also attempts to pull the system back from the deviated state to the original equilibrium state (Carver & Scheier, 1998). However, when the perturbation is too strong or the attractor is too weak, the system will turn into a chaotic condition waiting for a new order to be created. This frame has been adapted in observing the progress of treatment in depression (Hayes & Yasinski, 2015) and also in interpreting the individual differences in affective change (Kuppens, Oravecz, & Tuerlinckx, 2010).

Among various ways of visualizing state space, a system called State Space Grid (SSG; Hollenstein, 2007) has recently been used frequently in the field of developmental psychology (Granic & Hollenstein, 2003; Hollenstein, 2007). In SSG, the momentary state of each variable can be displayed on an axis of the state space grid with each point on the grid representing a single data point where individuals provided temporal information about the corresponding variables. Each state can be seen as the content of the system, e.g., such as the valence of the current emotion or level of momentary rumination. Constructs that describe how the whole system changes over time is conceived as the structure of a system. Various parameters can be extracted from SSG to describe the structure of a system. For example, duration represents to the duration of time a system stays in one state and visit refers to the number of time points a state appears in a system's on-going time series. Both content and structure of a system have

been considered to serve important roles in reflecting individual differences in daily dynamic affect and emotion regulation (Kuppens et al., 2010). Moreover, previous research has shown that the structure of dynamic emotional states in parent-children dyadic interactions plays a specific role in predicting psychopathology above and beyond the content of these emotional interactions (for a review, see Hollenstein et al., 2013).

One of the structural features of a nonlinear system that is of key interest here is the degree of instability, oftentimes referred to as *entropy*. In general, entropy is a measure of information that is generated as a system changes (Mitchell, 2009; Shannon & Weaver, 1949; Young, 2003). As information is generated over time, entropy also changes (Heath, 2000). The first statistical definition of entropy was proposed by Boltzmann as one of the main thermodynamic parameters, which changes as the whole system transform towards the equilibrium state and remains stable thereafter (Klimontovich, 2001). Perhaps the most widely known definition of entropy comes from information theory (Shannon & Weaver, 1949), in which entropy refers to the amount of information a signal can generate. Derived from Shannon's formula, SSG provides visit entropy of a system which is the sum of the relative frequencies with which every state is visited during the evolution of the dynamic process. When a system contains one attractor that has strong strength, the time series of the system may go back to this state more often which then generates less new information. This could be reflected by lower level of entropy. Alternatively, when a system contains a very weak attractor or several attractors, the states that would occur in the trajectory of the system may be more unpredictable. Thus, this kind of system would have relatively high level of entropy.

In sum, dynamic system theory has proven valuable in describing and analysing detailed temporal data sets in physiology, biology, and psychology. To successfully apply DST in momentary affect and emotion regulation in terms of their dynamics patterns requires intensive momentary measurement procedures that are sensitive to minor and transient changes. The combination of experience sampling methodology and dynamic system framework may serve as a more reliable and informative way to investigating daily dynamic patterns of rumination and emotion.

THESIS OUTLINE

The main aim of the current thesis is to investigate the underlying cognitive mechanisms of rumination and its impact on the onset, development and recurrence of depression. Given the importance of the attentional scope model of rumination in integrating mixed findings of previous studies, and in complementing contemporary theories, systematic research is needed to examine the predictions of this model. Moreover, it indicates a more complex way to understanding the attentional control mechanism of rumination. For example, the hypothesis of the model that narrow attentional scope can affect individuals' performance in processing all kinds of information when they do not feel depressed provides insight into a new way for the interference and prevention of rumination and depression, such as training attentional scope in individuals that are vulnerable to rumination when they have not become stuck in a cycle of negative emotions. Therefore, a series of studies presented in the following chapters sought to test the main ideas of this model.

In the first research line, we tried to find the attentional factors that contribute to the susceptibility to ruminate by focusing primarily on the association between rumination and attentional scope. We directly examine the predictions based on the attentional scope model of rumination that individual differences in attentional scope may impact the tendency to ruminate, and that changes in attentional scope should influence people's engagement in rumination. Therefore, we investigated whether there is a close relationship between attentional scope and rumination by conducting two eye-movement experiments in which attentional scope was measured while participants were reading sentences (Chapter 2 and 3). To explore whether characteristics of the sentences have impact on the relation between attentional scope and rumination, different types of sentences were employed in these two experiments. While the feature of self-relevance was examined in Chapter 2 by using neutral sentences that involve self- and other-related content, the feature of valence was inspected in Chapter 3 by including both neutral and emotional sentences as reading material. Based on the findings from Chapter 2 and 3, a multiple-session training in which the direction of causality between attentional scope and rumination was examined (Chapter 4).

In the second research line, we investigated the dynamic mechanisms of rumination in daily life by analysing the dynamic patterns in ruminative thinking and affect which may help us to understand how rumination develops into a maladaptive habit in daily life that has a detrimental influence on the onset and maintenance of depression. In the first study, we sought to examine individual fluctuations of negative mood and the occurrence of rumination in remitted depressed patients based on electronic daily dairy assessment of their momentary mood and rumination (Chapter 5). Specifically, we used a dynamic systems framework: state space, to explore their dynamic patterns. In line with the findings of Chapter 5 that the dynamic systems framework could be considered as a useful way to detect and measure the subtle alterations of the co-occurrence between two momentary measured constructs, the second study (Chapter 6) conducted in a broad range of population and sought to test whether the structure attribute (i.e., entropy) of the dynamics in rumination and affect in daily life has a specific contribution in predicting future trait rumination and depressive symptoms at six-week follow-up.

Below we describe the details of each chapter.

In **Chapter 2**, we investigated the association between attentional scope and rumination in processing neutral information that involves self- and other-related content. In order to study attention in a more direct manner, we used a moving window task (McConkie & Rayner, 1975) in the current study, which is a well-validated eye movement paradigm to measure attentional scope in perceptual level (Pollatsek, Rayner, Fischer, & Reichle, 1999; Rayner, 2014). Typically in the task, participants are asked to read a sentence and then provide a response to see the next sentence. There is a window on the screen moving with participants' eye movement only through which one could see the letters of the sentence while the text outside the window is masked. The width of the window is manipulated in each block so that when the window is narrower than individuals' attentional scope they would read the sentence with more difficulties than when the window is as large as or larger than their attentional scope. Based on the predictions of attentional scope model of rumination, we assumed that individuals with high levels of rumination relative to those with low levels of rumination may show a narrower perceptual scope in processing neutral information.

In **Chapter 3**, we tried to extend the findings of Chapter 2 about relation between attentional scope and rumination from neutral stimuli to emotional stimuli. Based on the findings of Chapter 2, we used the same moving window paradigm and included not only neutral sentences but also positive and negative sentences. Therefore, the aim of this study was to investigate whether people with different levels of trait rumination have different perceptual attentional breadth when processing both neutral and emotional material. Further, we also tried to explore whether the relation between attentional scope and trait rumination would be influenced by different valence of information. According to the attentional scope model of rumination (Whitmer & Gotlib, 2013) and our previous findings, we predicted that high ruminators relative to low ruminators would show narrowed attentional scope when processing both neutral and emotional faces. We also assumed that high ruminators would perform differently when processing negative information relative to other kinds of information.

In **Chapter 4**, we further explored the causal link between attentional scope and rumination. Based on the attentional scope model of rumination (Whitmer & Gotlib, 2013), people's attentional scope might influence the extent to which they engage in rumination, even after controlling for the mood state. Therefore, the aim of this experiment was to investigate the influence of different attentional scope on rumination. Specifically, we examined whether attentional breadth can be changed through such intended training manipulation and, if so, whether the attentional effect of these manipulations would be evident on state rumination induced in lab.

In **Chapter 5**, we explored the predictive effect of the relation between mood and rumination on depressive symptoms in remitted depressed (RMD) patients. In their initial study (Huffziger et al., 2013), both RMD patients and healthy controls were given, ten times a day within two days, an assessment of momentary mood and ruminative self-focus (Moberly & Watkins, 2008). We reanalysed the data by using dynamic system methodology: state space grid analysis (Hollenstein, 2013; Lamey, Hollenstein, Lewis, & Granic, 2004). The latter methodology elucidates the dynamic relation between different constructs in function of time.

Chapter 6 examined whether dynamic patterns in rumination and affect, expressed using entropy, could predict trait rumination and depressive symptoms. In

the previous study (Chapter 5), given that daily assessments were conducted during a relatively short time period where participants were mostly in a neutral or positive mood state, it could be assumed that the amount of variability observed in mood and rumination might be larger in a more prolonged assessment. Thus, the current experience sampling study extended the daily measurement into eight times a day over seven days. Moreover, our previous study (Chapter 5) found that a heightened level of entropy has detrimental effects specifically in the remitted depressed patients relative to healthy controls. This suggests that there might be different predictive effects of entropy depending on the extent to which people are vulnerable to depression. However, the healthy controls in this study (Huffziger et al., 2013; Koster et al., 2015) were selected strictly as a comparative group to remitted depressive group which thus had a relatively low depression scores at baseline. It remains unclear whether the dynamics of rumination and affect, in a more general population, influence future depressive symptoms. Therefore, the current experience sampling study recruited unselected sample which contains a wide range of trait rumination. In addition, in order to investigate whether the structure of dynamic patterns (i.e., entropy) of momentary rumination and affect in daily life plays specific role in predicting future trait rumination and depressive symptoms, content of dynamic patterns and relative weight of their contribution were explored as well.

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CHAPTER 2

TESTING THE ATTENTIONAL SCOPE MODEL OF RUMINATION: AN EYE-TRACKING STUDY USING THE MOVING WINDOW PARADIGM[1]

ABSTRACT

Attentional processes are considered to play an important role in information processing in rumination. The attentional scope model of rumination predicts that rumination is associated with a narrowed attentional scope which magnifies emotional responding and reduces problem-solving. This study examined key predictions of the model by using a moving window paradigm, allowing for a more direct measurement of attentional scope at a perceptual level. High and low trait ruminators were asked to read self-related and other-related sentences under small, medium, large, and no moving window conditions while their visual fixations during reading were recorded. Results showed significant group differences in the small window size condition, with the high rumination group processing faster and making fewer fixations when reading the sentences. Further analyses confirmed that differences remained after controlling for mood state and the level of depression. These findings support the key predictions of the attentional scope model of rumination, indicating that people with high levels of trait rumination are characterized by a narrower attentional scope when processing information. Theoretical and clinical implications in relation to rumination are discussed.

[1]Based on Fang, L., Sanchez, A., & Koster, E.H.W. (2017). Testing the attentional scope model of rumination: An eye-tracking study using the moving window paradigm. *Biological Psychology, 123,* 278-285. DOI: 10.1016/j.biopsycho.2016.10.011.

INTRODUCTION

Rumination is considered a form of responding to negative mood that focuses in a perseverative and repetitive manner on the implications, causes and meanings of one's feelings and problems (Nolen-Hoeksema, 1991). It is one of the most important cognitive risk factors for development and maintenance of depressive symptoms (Mor & Winquist, 2002; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Previous studies mostly focused on the negative content of rumination (Watkins, 2008), whereas more recent research has begun to investigate the mechanisms involved in the persistent use of rumination (Nolen-Hoeksema et al., 2008). Cognitive control, which involves top down control in processing, updating, and inhibiting of information has been shown to play a critical role in depression (Disner, Beevers, Haigh, & Beck, 2011) and specifically in rumination (Joormann, 2010; Koster, De Lissnyder, Derakhshan, & De Raedt, 2011). Therefore, investigation of the influence of rumination on information processing may help to gain a better understanding on the underlying mechanism of rumination and provide insights into prevention and treatment of depression.

Several theoretical frameworks have been developed to conceptualize the information-processing mechanisms that contribute to the persistence in the use of ruminative response styles (i.e., trait rumination). For example, some cognitive views propose that persistent rumination is associated with deficient inhibition (Joormann, 2010) and impaired disengagement from negative self-related information (Koster et al., 2011). Recently, a complementary framework has been proposed by Whitmer and Gotlib (2013), which posits that *attentional scope* is an important factor that affects the repetitive nature of thinking in trait ruminators. Attentional scope here has a broad definition and can refer both to the amount of information that is directly perceived from the environment as well as to the amount of information that is activated in working memory, where the perceived information is temporarily stored and manipulated. Overall, the attentional scope model of rumination (Whitmer & Gotlib, 2013) proposes that a limited attentional scope accounts for various characteristics observed in high trait rumination: in a neutral mood, high trait rumination is frequently associated with a narrower attentional scope which sometimes benefits to task-related information processing (Altarmirano, Miyake, & Whitmer, 2010). However, under

negative mood states, high trait rumination would be associated with a stronger focus on the causes and problems related to distress, at the expense of processing other information relevant for problem solving. Accordingly, the attentional scope model of rumination predicts that people with high levels of rumination would be characterized by a narrow attention scope even when they are in a neutral mood and are processing neutral information. Then, as their negative mood increases or positive mood decreases, high trait ruminators' attentional scope will become increasingly narrow by only focusing on negative self-related themes. This model also posits that people with low rumination levels are characterized by a broader attentional scope, which reduces their level of ruminative thinking by increasing their chance to reallocate attention to other sources of information or distracting stimuli.

Although the attentional scope model provides an explanation for a large number of previous findings in relation to rumination and information-processing (Altamirano, Miyake, & Whitmer, 2010; Joormann & Tran, 2009), only few empirical studies directly examined the model's predictions on attentional scope at a perceptual level. In a recent study (Grol, Hertel, Koster, & De Raedt, 2015), healthy undergraduates were induced to either engage in a state of rumination or in a state of problem-solving after which their visuospatial attentional scope towards self- or other-related information was examined. This study found that participants with a higher level of trait rumination who underwent the state rumination induction showed a more narrow attentional scope for self-related information relative to other-related information. Moreover, in a second experiment, Grol et al. (2015) also demonstrated that even in absence of a manipulation of rumination state, higher levels of trait rumination (i.e., brooding) were related to a more narrow scope of attention for self-related information relative to other-related information. This suggests that ruminative thinking is associated with a narrowed attentional scope in visual attention, especially when confronted with self-related information.

Although results from Grol et al. (2015) are promising in clarifying the association between rumination and attentional scope, a drawback is that the manipulation of self-relevant information was rather limited as this entailed presenting the word "me" versus another two letters. Moreover, the task was a rather complicated dual-task where inferences on attention were purely based on accuracy rates. Further

research is required to clarify whether rumination is specifically associated with narrowed attentional scope for self-relevant information or whether this impairment emerges for other information. Moreover, the approach used in Grol et al. (2015) and other frequently employed methodologies (e.g., *Global-Local Navon Letter task*, Navon, 1977) rely on indirect indices to estimate perceptual processes of attentional scope (e.g., participants' detection accuracy, reaction times). Hence, it seems crucial to investigate the relation between rumination and attentional scope using more direct measures of individuals' natural attentional scope for different types of information (i.e., self-related vs. other-related neutral information).

The current study

The current study was designed to explore the association between trait rumination and attentional scope in a more direct manner. We used a moving window task (McConkie & Rayner, 1975), which is a well-validated eye movement paradigm to measure attentional scope at the perceptual level (Pollatsek, Rayner, Fischer, & Reichle, 1999; Rayner, 2014). During this task, there is a window frame on the screen moving with participants' eye movements through which one can only see a limited amount of letters belonging to a sentence while the text outside the window is masked. To control how much information is available to participants, the width of the window is manipulated in different conditions (i.e., different sizes). The rationale of this task is that when the window size is smaller than a reader's attentional scope, the reading process will be different from the natural (i.e., no window and no mask) reading condition (Rayner, 1998). In contrast, the reading process will not differ from the natural reading condition when the window size is as large as or larger than a reader's attentional scope. Specifically, previous research using this paradigm has taken eye movements as a measure of reading process, showing that increased processing difficulty is correlated with slower reading rate, longer fixation duration and larger number of fixations (Pomplun, Reingold, & Shen, 2001; Rayner, Chace, Slattery, & Ashby, 2006). Therefore, in the present study, we used these eye movement indices (i.e., total sentence reading time, average fixation duration, number of fixations, and reading rate) as indicators of the degree of processing difficulty in reading during the

moving window task (Brzezicka, Krejtz, von Hecker, & Laubrock, 2012; Choi, Lowder, Ferreira, & Henderson, 2015 Häikiö, Bertram, Hyönä, & Niemi, 2009).

The first aim of the current study was to examine whether individual differences in the general tendency to ruminate (trait rumination) are associated with the magnitude of attentional scope at a perceptual level, as measured by eye movement indices at different window sizes during reading. Based on the prediction of the attentional scope model of rumination (Whitmer & Gotlib, 2013), we hypothesized that individuals with high levels of trait rumination would show a more narrow perceptual scope in comparison with individuals with low levels of trait rumination. This should be reflected by faster reading time (shorter total reading time, shorter average fixation duration, and faster reading rate) and less number of fixations when the window size is more compatible with the size of attentional scope of individuals with high rumination than the ones with low rumination (i.e., at small window size conditions). Furthermore, the attentional scope model of rumination states that the association between individual differences in rumination and attentional scope emerges not only in negative but also in neutral mood states. Therefore, participants' current mood state levels and depression levels were measured and included as covariates when significant effects that related to rumination group were observed.

Our second aim was to clarify under which conditions attentional narrowing effects can be observed. In the present study we used neutral sentences to examine the prediction of the attentional scope model of rumination that the association between trait rumination and attentional scope would emerge. In order to test whether the attentional narrowing effect would be dependent on the activation of self-representations, we manipulated the self-relevance of sentences. As suggested by Grol et al. (2015), trait rumination might be more strongly associated with narrowed attentional scope when confronted with self-related information rather than other-related information. Therefore, in the present study, we used both self- and other-related sentences as reading material to explore whether the presence of self-related information influences the association between trait rumination and attentional scope. In line with the evidence suggesting that ruminative thinking might be specifically related to narrowed attention towards self-related content (Grol et al., 2015), we

expected that there would be specific differences between individuals with high and low trait rumination when processing self-related sentences.

METHOD

Participants

Participants were prescreened on the basis of their scores on the Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Raes, Hermans, & Eelen, 2003) from a database of 305 students of Ghent University. Only individuals scoring in the highest 25% (high ruminators) and the lowest 25% (low ruminators) of the RRS were invited to participate in the current study. Based on the medium effect size (partial η^2 = .07) provided in the recent study of Brzezicka et al. (2012) using the similar moving window task on dysphoric and healthy control groups, we calculated the sample size needed to establish a similar effect using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). The analysis showed a total sample size of 52 for finding a significant within-between interaction is required with α = .05 and *power* = .80. In the current study, a final sample of 64 participants (32 low ruminators and 32 high ruminators) completed the experimental session. All participants were native Dutch speakers with normal or corrected-to-normal vision. They provided informed consent and received course credit for their participation.

Self-report measures

***Depression*.** Depressive symptoms were measured using the 42-item Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995). The DASS contains a set of three subscales (i.e., depression, anxiety and stress), among which the depression subscale is of particular interest in the present study. Participants were asked to rate on a 4-point scale according to their experience over the past week. Internal consistency of the depression subscale in this study was high, Cronbach's α = .92.

Rumination. We administered the 22-item Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Raes et al., 2003) to assess individual differences in the general tendency to ruminate (i.e., trait rumination). Participants were asked to rate on a 4-point scale how they typically respond when they are in negative or depressed mood. Internal consistency of the RRS in this study was high, Cronbach's α = .92. Additionally, in order to control the influence of state rumination, we also used the Momentary Ruminative Self-focus Inventory (MRSI; Mor, Marchetti, & Koster, 2013) before and after the moving window task. Participants were instructed to rate six items measuring their current degree of ruminative self-focused thinking on a 7-point scale ranging from "totally not agree" to "totally agree". Internal consistency of the MRSI was high, Cronbach's α = .87.

Mood. Since attentional scope has been shown to be influenced by mood (Baas, De Dreu, & Nijstad, 2008), we also assessed mood state along with the measure of state rumination so as to control its potential influence. Participants were asked to rate their mood (i.e., happy, sad and agitated) "at the moment" on three 100 mm Visual Analogue Scales (VAS) ranging from "neutral" to "as much as I could imagine".

Moving window task

In the current study, we used short (mean length of sentences = 58.3 characters, range: 55-66 characters), syntactically simple Dutch sentences with an average word frequency of 4.32 (*SD* = .38; range: 3.22-5.11), 60 of which are self-related (e.g., "I looked around and saw that the others were out of earshot.") and 60 of which are other-related (e.g., "John Cavendish frowned and changed the subject."). The sentences presented on the screen were selected from a pool of validated sentences obtaining from an Agatha Christie novel (Cop, Drieghe, & Duyck, 2015) and were randomly assigned to four blocks. The length of sentences and word frequency were matched among four window size conditions and only the length of sentences but not word frequency was matched between self- and other-related sentences as well[2]. Each

[2] Concerning the length of sentences (unit: character), there was no significant difference among different window size conditions, F (3, 116) = .01, p =.998. The average length of sentences (unit: character) for each window size condition was (1) small window size condition: M = 58.37, SD = 2.97; (2) medium window size condition: M = 58.33, SD = 2.96; (3) large window size condition: M = 58.23, SD =

block contained only one window size condition with 30 sentences (i.e., trials): (1) small window condition (5-8 characters visible; 12.5 mm of size; 1.19 degrees of visual angle); (2) medium window condition (10-13 characters; 25 mm; 2.39 deg.); (3) large window condition (22-25 characters; 50 mm; 4.77 deg.); and (4) no window condition (without restricted frame). The order of conditions was counterbalanced between participants and the trial presentation was randomized for each participant as well. In each trial, participants were instructed to first focus on a fixation cross presented on the left area of the screen. Once the eye-tracker detected a visual fixation of 200 ms on the fixation cross, the sentence appeared on the screen. Participants were instructed to read the sentence by moving their eyes naturally from left to right once the sentence was presented. They can see a limited amount of the text through the invisible window frame whereas the text outside the window was masked with a blank so that no extra information outside the window can be perceived. As soon as they finished reading, they were asked to press the space bar to continue with the following trial. In order to assure that participants read the sentence carefully and understood its meaning, five easy questions regarding the content of the sentence were randomly presented in each condition after participants finished reading some of the sentences. Participants were asked to select the correct answer to the questions from two options.

Participants' eye movements were recorded using a Tobii TX300 eye-tracker system. This system employs a dual-Purkinje eye-tracking method (Crane & Steele, 1985) and samples eye-gaze coordinates at 300 Hz (i.e., a coordinates' estimation every 3.3 ms). Both stimulus presentation and eye movements' recording were controlled by E-prime Professional software (Schneider, Eschman, & Zuccolotto, 2012). The eye-tracking system synchronized automatically with the program at the start of each trial.

2.84; (4) no window size condition: *M* = 58.27, *SD* = 2.52. In addition, there was also no significant difference between self- and other-related sentences with regard to length of sentences, *t* (110) = 1.51, *p* = .133. The average length of characters for each content was (1) self-related sentences: *M* = 58.68, *SD* = 3.12; (2) other-related sentences: *M* = 57.92, *SD* = 2.38. Word frequency was obtained from Cop et al. (2015). There was no significant difference of word frequency among different window size condition, *F* (3, 116) = .15, *p* =.929. The average word frequency for each window size condition was (1) small window size condition: *M* = 4.32, *SD* = .39; (2) medium window size condition: *M* = 4.33, *SD* = .32; (3) large window size condition: *M* = 4.28, *SD* = .42; (4) no window size condition: *M* = 4.34, *SD* = .41. However, there was a significant difference of word frequency among different content, *t* (118) = 5.06, *p* < .001. The word frequency for each content was (1) self-related sentences: *M* = 4.48, *SD* = .32; (2) other-related sentences: *M* = 4.16, *SD* = .38.

Participants were seated approximately 60 cm from the eye tracker capture. Eye movement signals were converted to visual fixation data by using E-prime extensions for Tobii (i.e., Clearview PackageCalls). The area of interest comprised the area where the sentence was presented.

Procedure

After signing informed consent, participants were administered all the questionnaires including trait and state measures. Then they completed the eye-tracking calibration procedure and a practice block with the reading task (five trials). Following the practice block, the four blocks of the main experiment were presented with a short break in between. At the end of the experiment, participants were asked to fill in the state measures again and received course credits for their participation.

Data preparation and analytical strategy

A series of indices were derived from visual fixations recorded within the area of interest (Brzezicka et al., 2012; Inhoff & Radach, 1998; Rayner, 1998): (1) Total sentence reading time (the sum of all visual fixation durations within each sentence); (2) average fixation duration (the average of all visual fixation durations within each sentence); (3) the total number of fixations made during reading each sentence; and (4) reading rate (the number of words divided by total sentence reading time and then was transformed to words/min). All these indexes indicate the processing difficulty while reading the sentence (Brzezicka et al., 2012; Häikiö et al., 2009; Rayner, 2009; Whitford, O'Driscoll, Pack, Joober, Malla, & Titone, 2013). Visual fixations were considered when they were equal to and longer than 100 ms. Therefore, trials where the average fixation duration was less than 100 ms (range: 0-99 ms) were excluded (0.45 % trials in total). In addition, trials where the reading rate was equal and larger than 3 SD of each window size condition (range: 640.78-4333.33 words/min) were excluded (0.93% trials in total). The remaining of 7219 trials was included in the final data analysis.

We performed a series of linear mixed effect (LME) models separately for each of the four attention indices (i.e., total sentence reading time, average fixation

duration, number of fixations, and reading rate) in SPSS 19 (Baayen, Davidson, & Bates, 2008). Fixed effects included group (high rumination vs. low rumination), window size (small, medium, large, no window), content (self-related, other-related), and the interactions among these variables. Random effects included intercepts for subjects and items. In addition, to control for the influence of depression level and mood states on group-related interactions, depression (depression subscale in the DASS), and positive and negative mood state levels (VAS Positive and VAS Negative before completing the task) were included as covariates in the LME models when further analysed the interaction effects. Cohen's d was used to calculate the effect size of the difference between two groups.

RESULTS

Group characteristics

One participant was excluded because of relatively high levels of depression (> 3 SD in DASS depression subscale). Another two participants were excluded based on poor task performance (both sentence reading time and number of fixations were ≥ 3 SD). Demographic and psychological characteristics of the remaining 61 participants are presented in Table 1. No differences between the two groups were found concerning their age, t (44) = 1.59, p = .12. The high rumination group (27 female: 3 male) had a significantly higher ratio of females relative to males than the low rumination group (19 female: 12 male), χ^2 (1, N= 61) = 6.78, p < .01. As expected, there was a significant difference between groups (see Table 1 for details) in trait rumination, t (59) = 7.64, p < .001 and we also found a significant difference between groups in the level of depressive symptoms, t (37) = 4.48, p < .001. With regard to the state measures at baseline (before the experimental task), there was a significant difference between groups in positive mood state, t (52) = 2.94, p < .01, as well as in negative mood state, t (47) = 2.54, p < .05, but no significant difference between groups in arousal state, t (59) = 1.76, p = .08, as well as in state rumination, t (59) = 1.71, p = .09.

Table 1. *Characteristics of participants*.

	Group			
	High trait rumination (N = 30)		*Low trait rumination (N = 31)*	
	M	*SD*	*M*	*SD*
Age	19.43	2.50	18.61	1.36
Gender (female:male)	27:3		19:12	
DASS_Depression	9.83	7.66	3.16	2.84
RRS	50.97	9.57	34.10	7.60
MRSI_T1	27.27	7.58	24.16	6.60
MRSI_T2	19.33	8.66	19.45	6.59
VAS_positive_T1	42.33	30.69	62.45	21.77
VAS_positive_T2	35.67	28.45	54.00	26.30
VAS_negative_T1	28.63	29.49	12.84	17.28
VAS_negative_T2	25.27	29.53	11.74	15.72
VAS_agitated_T1	42.60	25.17	32.23	20.64
VAS_agitated_T2	29.03	24.40	23.74	21.49

Note: DASS, Depression Anxiety Stress Scales; RRS, Ruminative Response Scale; MRSI, Momentary Ruminative Self-focus Inventory; T1, Time 1 (before the experimental task); T2, Time 2 (after the experimental task); VAS, Visual Analogue Scale.

Total Sentence Reading Time

Results showed that window size, F (3, 7116.41) = 1425.18, p < .001, but not content, F (1, 28.01) = 0.43, p = .52, significantly predicted total sentence reading time. More importantly, analyses also showed that group, F (1, 58.95) = 5.91, p < .05, the interaction between group and window size, F (3, 7116.42) = 30.76, p < .001, and the interaction between group and content, F (1, 7116.05) = 8.19, p < .01, all significantly predicted total sentence reading time. No other significant interaction effects were found (all Fs < 1.43, ps > .23). The interactions were further analysed by conducting

separate LME models on each window size or on each content. The setting of models were similar as the main model (except we removed window size and content from the fixed effects), but we also added either mood states or depression as covariates to control for the influences of mood states or depression.

For the small window size condition, group significantly predicted total sentence time both when controlling for the influence of mood states, b = 1.21, SE = .46, t (56.92) = 2.64, p < .05, 95% CI = [0.29, 2.13], and when controlling for the influence of depression, b = 1.04, SE = .48, t (58.00) = 2.16, p < .05, 95% CI = [0.08, 2.00]. Consistent with our first hypothesis, the high rumination group required less time to read the sentences in this window size condition (i.e., lower total fixation duration during sentence reading) in comparison to the low rumination group (see Table 2 for details), indicating a more narrow attentional scope in the high rumination group relative to the low rumination group. In contrast, no significant main group effects were found for the other window size conditions (medium, large, no window), all ts < 1.59, all ps >.12. Overall, although the high rumination group showed less total sentence reading time than the low rumination group in general, the further LME models indicated that this difference was limited to the small window size conditions (small window condition: d = .48; other conditions: all ds < .25), with high ruminators reading faster than low ruminators in that specific condition (see Fig. 1a).

Additionally, the high rumination group generally used less time to read both the self- (d = .20) and other-related (d = .28) sentences relative to the low rumination group (see Table 2 for details). Specifically, for self-related sentences, group was found to significantly predict total sentence time when controlling for mood states, b = .50, SE = .24, t (56.95) = 2.04, p < .05, 95% CI = [0.01, 0.98], but not significant when controlling for depression, b = .40, SE = .26, t (58.03) = 1.53, p = .13, 95% CI = [-0.12, 0.93]. For other-related sentences, group also significantly predicted total sentence time when controlling for mood states, b = .72, SE = .28, t (56.86) = 2.61, p < .05, 95% CI = [0.17, 1.27], but not significant when controlling for depression, b = .56, SE = .29, t (57.90) = 1.91, p = .06, 95% CI = [-0.03, 1.15].

Table 2. *Means and standard deviations of all eye movement measures for high and low trait rumination groups.*

Eye movement measures	*Group*	*WS1*		*WS2*		*WS3*		*NW*		*Self-related*		*Other-related*	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Total Sentence Reading Time (s)	High	5.78	2.10	4.24	1.83	3.37	1.44	2.85	1.19	4.08	2.02	4.04	2.00
	Low	6.99	2.92	4.59	2.10	3.78	1.78	3.09	1.38	4.52	2.42	4.71	2.72
Average Fixation duration (s)	High	0.26	0.05	0.24	0.04	0.23	0.04	0.21	0.04	0.23	0.05	0.23	0.05
	Low	0.27	0.05	0.24	0.04	0.22	0.04	0.21	0.04	0.23	0.05	0.24	0.05
Number of fixations	High	21.97	6.93	18.02	7.08	15.00	5.81	13.84	5.62	17.30	7.15	17.11	7.10
	Low	25.46	8.43	19.27	7.18	16.77	6.81	14.59	5.63	18.76	7.59	19.27	8.70
Reading rate (words/min)	High	140.59	63.13	193.72	76.17	240.68	99.32	282.92	113.03	222.52	106.96	206.49	101.42
	Low	117.50	52.15	179.23	69.02	212.71	85.33	269.99	122.74	205.38	106.55	184.44	97.05

Note: High, the high trait rumination group; Low, the low trait rumination group; WS1, small window size condition; WS2, medium window size condition; WS3, large window size condition; NW, no window size condition; Self-related, self-related sentences; Other-related, other-related sentences.

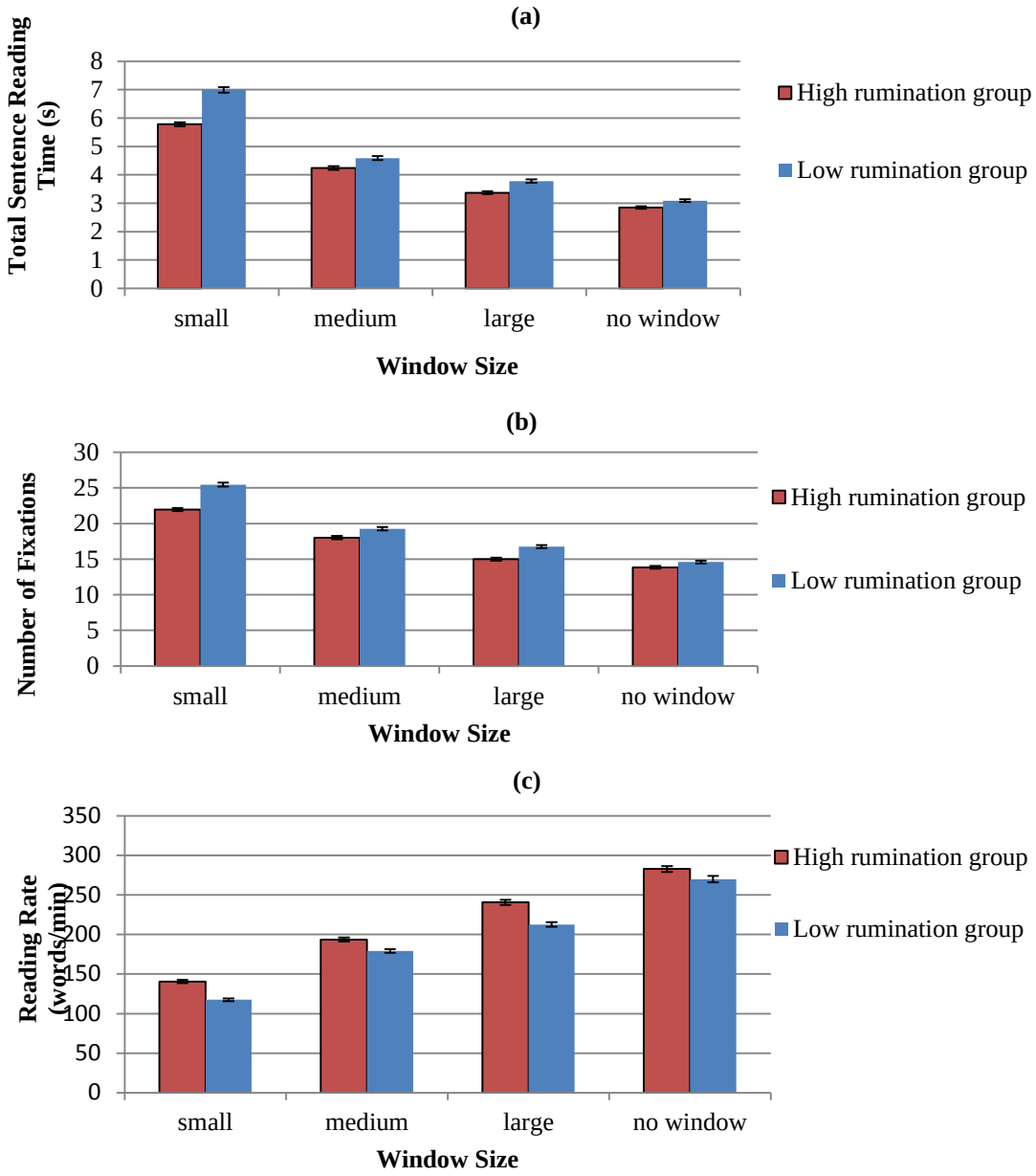

Fig.1. *Eye movement measures in each window size condition for high and low rumination groups: (a) Total sentence reading time, (b) Number of fixations, and (c) Reading rate. Error bars represent the standard errors of the means*.

Average Fixation Duration

The results revealed that window size, F (3, 7116.56) = 807.14, p < .001, and the interaction between group and window size, F (3, 7116.58) = 7.48, p < .001, both significantly predicted average fixation duration. The other main or interaction effects were not significant (all Fs < 2.60, ps > .12). However, when we examined the interaction by conducting separate LME models for each window size, no significant effects were found neither when controlling for mood states, nor when controlling for depression, all ts < 1.57, ps > .12.

Number of Fixations

The results showed that window size, F (3, 7116.34) = 951.32, p < .001, but not content, F (1, 28.01) = 0.13, p = .72, significantly predicted number of fixations. The results also revealed that group, F (1, 58.95) = 4.39, p < .05, the interaction between group and window size, F (3, 7116.35) = 17.83, p < .001, and the interaction between group and content, F (1, 7116.04) = 7.41, p < .01, all significantly predicted number of fixations. No other significant interaction effects were found (all Fs < 2.15, ps > .09). The interactions were further analyzed by conducting separate LME models on each window size or each content. The models specified were similar as the main model (except we removed window size and content from the fixed effects), but we also added either mood states or depression as covariates.

For the small window size condition, group significantly predicted number of fixations when controlling for the influence of mood states, b = 3.28, SE = 1.41, t (56.86) = 2.34, p < .05, 95% CI = [0.47, 6.10], but not when controlling for the influence of depression, b = 2.31, SE = 1.45, t (57.97) = 1.59, p = .12, 95% CI = [-0.59, 5.21]. The results indicated that when the influence of mood states was considered, the high rumination group was still found to use less number of fixations than the low rumination group when reading the sentences in the small window condition (see Table 2 for details). In contrast, no significant main group effects were found for the other window size conditions (medium, large, no window), all ts < 1.60, ps >.11. Overall, we found that the high rumination group used less number of fixations than the low

rumination group in general, but the results of separate LME models showed that this difference in function of trait rumination level was only significant in the small window size condition (small window condition: *d* = .45; other conditions: all *ds* < .28), with high ruminators displaying fewer fixations than low ruminators (see Fig. 1b).

In addition, the high rumination group mostly used less number of fixations for the other- (*d* = .27) but not the self-related (*d* = .20) sentences than the low rumination group (see Table 2 for details). Specifically, for self-related sentences, no significant effects of group were found neither when controlling for mood states nor when controlling for depression, all *ts* < 1.61, *ps* > .11. For other-related sentences, group was found to significantly predict the number of fixation when controlling for mood states, *b* = 2.21, *SE* = 1.04, *t* (56.84) = 2.12, *p* < .05, 95% CI = [0.13, 4.30], but not significant when controlling for depression, *b* = 1.46, *SE* = 1.08, *t* (57.86) = 1.36, *p* = .18, 95% CI = [-0.70, 3.61].

Reading Rate

The results showed that window size, *F* (3, 7116.20) = 1302.02, *p* < .001, content, *F* (1, 28.00) = 10.57, *p* < .01, and the interaction between window size and content, *F* (3, 7115.95) = 5.09, *p* < .01, all significantly predicted reading rate. Analyses also revealed that the interaction between group and window size, *F* (3, 7116.20) = 6.20, *p* < .001 significantly predicted reading rate. No other significant main or interaction effects were found (all *Fs* < 3.08, *ps* > .09). According to our main hypotheses, only group-related interactions were further analyzed by conducting separate LME models on each window size. The models specified were similar as the main model (except we removed window size and content from the fixed effects), but we also added either mood states or depression as covariates.

For the small window size condition, group significantly predicted reading rate when controlling for the influence of mood states, *b* = -24.62, *SE* = 11.59, *t* (56.55) = 2.12, *p* < .05, 95% CI = [-47.83, -1.40], and nearly significantly when controlling for the influence of depression, *b* = -24.36, *SE* = 12.24, *t* (57.59) = 1.99, *p* = .05, 95% CI = [-48.85, 0.14]. The results indicated that relative to the low rumination group, the high rumination group read faster in the small window size condition (see Table 2 for

details). In contrast, no significant main group effects were found for the other window size conditions (medium, large, no window), all *t*s < 1.86, all *ps* >.07. Overall, the results revealed that reading rate was significantly faster in the high rumination group than in the low rumination group only in the small window size condition (small window condition: *d* = .40; other conditions: all *ds* < .30; see Fig. 1c).

DISCUSSION

In the current study we examined key predictions of the attentional scope model of rumination (Whitmer & Gotlib, 2013). This model proposes that individuals with high levels of trait rumination are characterized by a narrower scope of attention. We investigated this claim using a moving window task where reading sentences in different types of window sizes provided an indication of the individual's attentional scope. The main results were (1) significant differences between high and low trait rumination groups in the small window size condition even after controlling for participants' current mood states and depressive levels, and (2) the association between individual differences in trait rumination and attentional scope was observed across all types of sentences. Below we discuss these results in more detail.

Regarding our first aim – clarifying whether individual differences in trait rumination are associated with differences in the magnitude of attentional scope – the differences between high and low trait rumination groups in the small window size condition suggest that individuals with different levels of trait rumination may have different sizes of attentional scope at the perceptual level. Based on the underlying rationale of the moving window paradigm (Rayner, 1998), individuals with a narrow attentional scope relative to individuals with a broader attentional scope are less affected when reading in reduced window size conditions (Brzezika et al., 2012; Häikiö et al., 2009; Whitford et al., 2013). In our study, participants in the high rumination group showed faster total reading time (i.e., shorter total fixation time), a fewer number of fixations and faster reading rate than participants in the low rumination group in the small window size condition when differences in current mood levels and depression levels were controlled. This suggests that relative to people with low level of

trait rumination, people with high levels of trait rumination were less sensitive to the small window manipulation and therefore may have a narrower attentional scope at the perceptual level. Interestingly, this association was not observed in the average fixation duration. These differential results indicate that overall shorter reading times observed in the high trait rumination group in the small window condition were not accounted by making fixations with a shorter duration but by using a lower number of fixations to read the sentence (i.e., requiring less time to complete the full reading pattern). Overall, these findings support the hypothesis of the attentional scope model of rumination (Whitmer & Gotlib, 2013) postulating that individuals characterized by a persistent use of rumination have a narrow attentional scope even in the processing of neutral information.

Our second aim was to clarify whether trait rumination differences in attentional scope specifically emerge under conditions of self-related information processing. A recent study (Grol et al., 2015) showed that trait rumination level was related with a more narrowed attentional scope for self-related compared with other-related information. In our current study, we found that in the small window condition, the high rumination group showed a more narrow attentional scope across all types of sentences after controlling for the current mood and depressive levels, suggesting that the association between trait rumination and attentional scope may not influence by the presence of self-related information. Notably, although the high rumination group, relative to the low rumination group, generally used faster total reading time and less number of fixations for both types of sentences, these effects were not significant when introducing depression levels as covariate, indicating that after controlling individual's depression level, the high rumination group was not significantly different from the low rumination group in processing both types of sentences.

Furthermore, since we used neutral sentences as reading material in our study, the current results provide supportive evidence for the prediction of the attentional scope model of rumination that individual differences in attentional scope will not only affect the processing of negative information but extend to other types of information (Whitmer & Gotlib, 2013). Nevertheless, the fact that we only employed neutral sentences in our study prevents us from driving strong conclusions on whether attentional scope differences as a function of trait rumination level occur in the same

way for different sources of emotional information. Further studies will require testing attentional scope during reading of sentences with different valences (positive, negative and neutral) in order to fully test these theoretical predictions.

The current findings may have clinical implications for the prevention and treatment of depression, specifically when attempting to reduce maladaptive processes of persistent rumination. A wealth of empirical research has been trying to reduce rumination by using procedures to target attentional processes using computerized training. Interestingly, the effects of such training procedures have been mixed (Mor & Daches, 2015). Notably, these procedures have mainly targeted attentional orienting. In light of the attentional scope model of rumination's proposals and based on our current findings, individual differences in attentional scope may play a critical role in the persistent use of rumination. Therefore, training procedures aimed to target cognitive control processes of attentional scope (e.g., improving the ability to enlarge the perceptual scope or working memory representation repertoire and to disengage from focused information) may be a promising avenue to reduce persistent use of rumination. Moreover, we observed an association of attentional scope and trait rumination when processing neutral information, not accounted by differences in their mood states and depression levels. Thus, contrasting with current interventions that specifically focus on modifying negative information processing (e.g., Daches, Mor, & Hertel, 2015), attentional scope training might also be implemented as a general cognitive control training approach in order to reduce trait rumination (Cohen, Mor, & Henik, 2015; Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015).

The present study has some limitations. First, due to the cross-sectional nature of our study, we cannot make causal inferences about the direction of causality between trait rumination and attentional scope. However, previous research has found that individuals characterized by a high trait rumination level showed narrowed attentional scope when they were induced to elevate their rumination state (Grol et al., 2015), which might afford a potential causal direction. Further research should also develop manipulations of the attentional scope in order to investigate its impact on changes in rumination levels at short duration (i.e., state rumination) as well as at longer periods (i.e., trait rumination). Second, our design did not allow to fully testing the predictions derived from the attentional scope model of rumination. This model

also attempts to explain the development of rumination when individual's mood changes from neutral to depressed. Specifically, it predicts that when people with a tendency to ruminate feel depressed, negative mood would bias ruminators' attentional scope to only focus on negative personal relevant information. However, in the present study, we only used neutral sentences and did not manipulate individual's negative mood state. Therefore, we were not able to extend our findings to the examination of depressed mood effects in the association between trait rumination and attentional scope for negative self-related information. Further research is warranted to test this issue. Third, word frequency was not controlled for different content, as the word frequency of self-related sentences was higher than other-related sentences. However, among all the reading indexes, we only found a significant main effect of content in reading rate which showed a faster reading rate for self-related sentences (M = 213.75, SD = 107.08) than other-related sentences (M = 195.20, SD = 99.80). Also, no significant three-way interaction effects among group, window size and content were found for all four indexes. These may suggest that the differences of word frequency between self- and other-related sentences did not influence the main results of the current study.

In summary, the current research is the first eye movement study exploring the association between trait rumination and attentional scope at the perceptual level. Our findings provide supportive evidence for the key prediction of the attentional scope model of rumination that people with persistent use of rumination have a more narrow attentional scope in the processing of neutral information. This effect was observed during reading of sentences including both self-related and other-related neutral information in the most difficult reading condition (i.e., the small window size condition), and was not accounted by mood state and depressive levels.

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CHAPTER 3

RELATION BETWEEN ATTENTIONAL SCOPE AND RUMINATION: EXAMINATION OF VALENCE-SPECIFICITY USING A GAZE-CONTINGENT MOVING WINDOW PARADIGM[1]

ABSTRACT

Rumination has been considered as a relatively maladaptive form of repetitive thinking with a marked impact on mood. Individual differences in attentional scope have been proposed as an important mechanism making some individuals more prone to ruminate than others. The attentional scope model of rumination posits that rumination is related to a narrowed attentional scope, which may affect the processing of neutral and emotional information. This study aimed to extend research on the relation between rumination and attentional scope while processing neutral, positive and negative information. To assess individual's attentional scope, a moving window task was applied which involved reading both neutral and emotional sentences. The result of reading rate indicated that individuals with higher levels of trait rumination showed a narrower attentional scope across all types of sentences. In addition, the total reading time of individuals with higher levels of trait rumination was shorter when processing neutral and positive sentences through a constrained window frame, but this was not the case when processing negative sentences. These findings suggest that even though high trait ruminators use an overall constrained manner of processing all types of information, they may still process negative information differently compared with other types of information.

[1]Based on Fang, L., Sanchez, A., & Koster, E.H.W. (2017). Attentional scope, rumination, and processing of emotional information: An eye-tracking study. Manuscript submitted to publication.

INTRODUCTION

For decades, great efforts have been made to investigate rumination and its impact on depression. According to the response styles theory, rumination is characterized by repetitive self-focused thinking about the implications, causes, and meanings of one's negative feelings (Nolen-Hoeksema, 1991). Accumulating evidence has shown that rumination has a deleterious impact on mood, problem solving, and cognitive functioning (Watkins, 2008). It has also been found that habitual use of rumination prospectively predicts the onset and maintenance of depression (Just & Alloy, 1997; Kuehner & Weber, 1999; Nolen-Hoeksema & Morrow, 1993). Therefore, identifying factors that make individuals more vulnerable to engage in persistent rumination is essential to understand and potentially treat this key cognitive risk factor for depression.

A number of information-processing factors have been associated with the repetitive nature of rumination. For instance, cognitive inhibition impairments (i.e., problems in the ability to inhibit the processing of irrelevant information) have been considered one of the main mechanisms contributing to difficulties interrupting persistent negative thoughts in high trait rumination (Joormann, 2010). Furthermore, impaired disengagement of attention from negative information has also been proposed to account for limited control over negative thinking in high ruminators (Koster, De Lissnyder, Derakhshan, & De Raedt, 2011). Inspired by research revealing that sustained self-focus of high ruminators may not be limited to negative information (Joormann & Tran, 2009) and that high ruminators tend to show better performance on tasks requiring focused attention (Altamirano, Miyake, & Whitmer, 2010; Zetsche & Joormann, 2011), recently a novel theoretical model, the attentional scope model of rumination, has been proposed (Whitmer & Gotlib, 2013). In this framework, attentional scope is considered the primary source of individual differences that determines the susceptibility to rumination in response to negative affect. Specifically, this model assumes that high ruminators may process all types of information in a more focused manner when they are in neutral mood (having beneficial effects in relation to certain tasks), compared to low ruminators. Yet, when they feel sad or depressed, their

attentional scopes may become even more narrow towards negative mood-relevant information, leading to an unproductive narrow focus on self-related themes.

The most distinctive characteristic of the attentional scope model of rumination is that it argues that the attentional scope of individuals can affect their processing of all types of information, when they are in a neutral mood. Hence, it can provide an explanation for findings showing that levels of rumination influence the processing of not only negative material but a broad range of information (Hilt, Leitzke, & Pollak, 2016; LeMoult, Arditte, D'Avanzato, & Joormann, 2013). In a recent study trying to investigate the relation between rumination and attentional scope (Fang, Sanchez, & Koster, 2017), undergraduates were preselected on high versus low levels of trait rumination. Participants were asked to perform a moving window task during which neutral sentences were presented and their eye movements while reading were recorded. In this task, participants read sentences that were either presented without or with varying window sizes that restricted participants' reading scope. The content of a sentence that can be seen depends on the size of an invisible window frame which was moved contingent with gaze position. Individual's attentional scope is inferred by comparing performance on different window size conditions and baseline condition (no window condition). We found that, when reading neutral sentences, individuals in the high trait rumination group were better able to read sentences presented in a small window size than individuals low in trait rumination. This study provided direct evidence of a narrower attentional scope (at the perceptual level) in habitual ruminators, as predicted by the attentional scope model of rumination. Nevertheless, due to the fact that only neutral sentences were used in this study, it is unclear whether the results could be generalized to other types of information, particularly emotional positive and negative information.

Concerning processing of negative information, the attentional scope model of rumination predicts more focused attention on negative information for individuals with higher levels rumination when they feel depressed, due to the negative mood congruent effect. However, already in a neutral mood, this narrow focus would be present for processing information in general. Nevertheless, the model has not precisely delineated whether individuals with high levels of rumination still process negative material differently from other types of information, in a neutral mood.

Previous studies have shown that high levels of trait rumination are associated with attentional bias towards negative information relative to positive or/and neutral stimuli (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Donaldson, Lam, & Mathews, 2007; Duque, Sanchez & Vazquez, 2014). Noteworthy, in these studies, valence-specific attentional bias in relation to rumination remained significant, even after statistically controlling for the influence of depressive symptoms. Thus, it would be interesting to explore whether specific patterns of attentional narrowing can be observed during reading emotional information after controlling for mood state.

The present study

The present study sought to extend the research in relation between rumination and attentional scope using the moving window paradigm (Fang et al., 2017). Based on the assumptions of the attentional scope model of rumination, according to which individual differences in attentional scope would affect performance during the processing of neutral and emotional information (Whitmer & Gotlib, 2013), our first hypothesis was that trait rumination is associated with performance benefits when processing neutral and emotional sentences in a restricted attentional window. In line with previous research using this paradigm (Fang et al., 2017), we adapted the moving window task to evaluate attentional scope (McConkie & Rayner, 1975). Typically, this task requires participants to read a sentence through an invisible window frame. The text within the window frame can be seen whereas the text outside of it is masked. The rationale of this paradigm is that, if the attentional scope of an individual is larger than the window frame, then the limited window would make it more difficult to process the sentence than natural reading. People with a narrower attentional scope may be less influenced by the reduced window size than people with a broader attentional scope. Second, to test whether attentional scope is influenced by the valence of the sentence, we presented different types of emotional stimuli. According to previous studies indicating rumination-related differential processing of negative information (e.g., De Lissnyder et al., 2010; Donaldson et al., 2007), we predicted that high ruminators show a narrower attentional scope while processing negative sentences.

METHOD

Participants

In the current study, a total of 64 participants (36 females, 28 males) completed the experimental session. They were native Dutch speakers with normal or corrected-to-normal vision. All participants provided informed consent and received reimbursement for their participation.

Self-report measures

Symptom and trait measurements. Depressive symptoms were assessed with the 21-item Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996; Van der Does, 2002). The occurrence and severity of depressive symptoms over the past two weeks were rated by participants on a 4-point scale (Cronbach's α = .84). Trait rumination was assessed with the 22-item Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Raes, Hermans, & Eelen, 2003; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Participants were asked to rate items on a 4-point scale while thinking about how they usually respond when they are in a negative or depressed mood (Cronbach's α = .93).

State measurements. Provided that the aim of our study was to examine the relation between attentional scope and rumination in a neutral mood condition, mood state should be assessed and controlled. In this regard, mood (i.e., happy, sad and agitated) was assessed on three 100 mm Visual Analogue Scales (VAS) ranging from "neutral" to "as much as I could imagine" (see Rossi & Pourtois, 2012). Additionally, in order to control the influence of state rumination, the 6-item Momentary Ruminative Self-focus Inventory (MRSI; Mor, Marchetti, & Koster, 2013) was employed before and after the moving window task. Participants were asked to rate the extent of ruminative self-focused thinking at the moment on a 7-point scale ranging from "totally not agree" to "totally agree" (Cronbach's α = .82).

Moving window task

A series of short (mean length of sentences = 30.10 characters, range: 22-47 characters) and syntactically simple Dutch sentences were used in the current study. The reading material comprised three types of valence, which were 60 positive (e.g., "I am a cherish person."), 60 negative (e.g., "I am a born loser."), and 60 neutral sentences (e.g., "I relax during holidays."). The positive and negative sentences were selected from a pool of validated self-referent sentences obtaining from a previous study (Everaert, Duyck, & Koster, 2014). In line with previous studies (Everaert et al., 2014; Sanchez, Everaert, De Putter, Mueller, & Koster, 2015), neutral sentences were generated using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004) and matched with emotional sentences on word length and frequency. All the sentences were randomly assigned to four blocks. The length of sentences was matched among the four window size conditions and the three types of valence. Four different window size conditions were used: (1) small window condition (2-4 characters visible; 12.5 mm of size); (2) medium window condition (6-8 characters; 25 mm.); (3) large window condition (12-14 characters; 50 mm); and (4) no window condition (without restricted frame). Each window size condition consisted of 3 blocks (i.e., positive, negative, and neutral block), each of which contained 15 sentences (trials). The order of the window size conditions was counterbalanced among participants. The presentation of blocks within each window size condition was also randomized for every participant.

At the beginning of each trial, a fixation cross was presented on the left side of the screen. Participants were required to look at the cross for at least 200 ms until the target sentence was displayed on the screen. They were then asked to read the whole sentence and to press the space bar as soon as they understood the meaning of the sentence. In those three moving window conditions, only limited numbers of characters could be seen through the invisible window frame (larger, or smaller, depending on the condition) and the window frame was moving contingent to the individual's gaze. Thus, participants were instructed to move their eyes naturally from left to right so that they can read the full sentence. The rest of the sentence outside the window frame was blanked. After several sentences, participants were randomly asked to answer a simple question concerning the content of the preceding sentence by choosing the correct answer from two options. This encouraged participants to process the meaning of the sentences, as instructed.

In line with our previous study (Fang et al., 2017), attention indices comprise total sentence reading time, number of fixations, and reading rate. Specifically, the total sentence reading time was the summation of all fixations duration within a sentence. The number of fixations was the total number of fixations that were recorded within a sentence. Reading rate was the average number of words processed per minute.

Eye tracking

Eye movements during the moving window task were recorded with a Tobii TX300 eye-tracker system, which utilizes a dual-Purkinje eye-tracking method (Crane & Steele, 1985) and samples eye-gaze coordinates at 300 Hz (i.e., a coordinates' estimation every 3.3 ms). E-prime Professional software (Schneider, Eschman, & Zuccolotto, 2012) was used to run the presentation of experimental stimuli and control the recording of eye movements. The eye-tracking system synchronized automatically with E-prime at the start of each trial. The distance between participants and the eye tracker was approximately 60 cm. Eye movement signals were converted to visual fixation data by using E-prime extensions for Tobii (i.e., Clearview PackageCalls).

Procedure

Participants were first asked to complete a written informed consent and to complete self-report questionnaires with regard to depressive symptoms, trait rumination, and state measurements at baseline. Then, they were instructed to perform the moving window task, which included one practice block and four main experiment blocks (one for each window condition, randomly presented). State measurements were measured again immediately following the moving window task performance. At the end of the experiment, participants were debriefed and received reimbursement for their participation.

Data preparation and analytical strategy

The criteria for data exclusion were the same as in the previous study using this paradigm (Fang et al., 2017). Thus, all trials with average fixation duration < 100 ms

were excluded (0.36% trials in total), and trials in which reading time was equal or larger than 3 SD of each window size condition were excluded as well (1.11% trials in total). Final data analyses were conducted on the remaining 9933 observations (98.53% trails in total).

A series of linear mixed effect (LME) models were performed (Baayen, Davidson, & Bates, 2008), for each of the four attentional scope indices (i.e., total sentence reading time, number of fixations, and reading rate) in R version 3.3.2 using lme4 package (Bates, Maechler, Boler, & Walker, 2015). In each LME model, the variables included in fixed effects were adjusted based on different purposes whereas intercepts for participants and items were always comprised in the random effects. We first tested the full model in which the centered RRS score (continuous covariate), window size (small, medium, large, and no window), valence of sentence (negative, neutral, and positive), and corresponding interactions among these variables were entered as fixed effects.

To test our hypothesis, a two-way interaction between window size and the RRS score was expected for the first hypothesis, and a three-way interaction between window size, the RRS score, and valence was expected for testing the second hypothesis. In the further analyses of the expected interactions, separate mixed models were conducted in each window size condition (or for each valence of sentence), with RRS included in fixed effects as continuous covariate, and participant and item included as random effects while controlling for baseline positive and negative mood[2]. In order to avoid collinearity, all continuous variables were centered before the LME analysis.

[2] We also entered the state rumination score as covariance in all models and found similar results as when they were not involved in the models. Given that the attentional scope model of rumination mainly stresses the influence of mood state on attentional scope, we did not put the related results in the main text.

RESULTS

Group characteristics

One participant was excluded because of a highly elevated depression score (BDI-score of 37; > 3 SD in BDI-II). Two participants were excluded for not completing the questionnaires. Five participants were ruled out due to poor task performance (standard deviation score of total reading time and number of fixation ≥ 3). The characteristics of the remaining 56 participants (age: *M* = 20.32, *SD* = 2.82; 31 female) are shown in Table 1. Our sample showed sufficient variation in trait rumination (range: 22-70).

Table1. *Characteristics of participants (N = 56)*.

	Mean	*SD*	*Range*
Age	20.32	2.82	17-31
Gender (female:male)	31:25		
BDI-II	9.80	6.47	0-24
RRS	39.77	12.41	22-70
MRSI T1	25.36	7.25	7-40
MRSI T2	24.54	6.58	11-40
VAS_positive T1	50.09	28.44	0-93
VAS_positive T2	52.50	28.14	0-97
VAS_negative T1	15.84	20.32	0-94
VAS_negative T2	12.48	15.22	0-55
VAS_agitated T1	30.30	25.58	0-95
VAS_agitated T2	31.12	24.43	0-84

Note: BDI-II, Beck Depression Inventroy-II; RRS, Ruminative Response Scale; MRSI, Momentary Ruminative Self-focus Inventory; T1, Time 1 (before the experimental task); T2, Time 2 (after the experimental task); VAS, Visual Analogue Scale.

Total Sentence Reading Time

The results of the full model showed a significant effect of the RRS, F (1, 54.00) = 6.07, $p < .05$, window size, F (3, 168.00) = 114.21, $p < .001$, and a significant two-way interaction between window size and RRS, F (3, 9835.10) = 15.82, $p < .001$. Moreover, the three-way interaction among window size, RRS, and valence was also significant, F (6, 9834.80) = 2.76, $p < .05$ (other $Fs < 1.76$, $ps > .17$) (see Fig. 1). To clarify the three-

way interaction, separate mixed models for different valences showed that the interaction between window size and RRS was significant for neutral sentences, F (3, 3124.88) = 3.12, $p < .05$, and for positive sentences, F (3, 2986.09) = 17.05, $p < .001$, but not for negative sentences, F (3, 2979.73) = 1.88, $p = .13$. Therefore, we conducted separate mixed model only for neutral and positive sentences in each different window size condition while controlling for baseline mood.

For neutral sentences, there was a tendency that RRS predicted performance in the small window condition, b = -25.97, SE = 14.16, t (51.14) = 1.83, p = .07, 95% CI = [-53.37, 1.43], in the medium window condition, b = -13.25, SE = 7.06, t (50.86) = 1.88, p = .07, 95% CI = [-26.90, 0.41], and in the large window condition, b = -10.77, SE = 5.03, t (52.03) = 2.14, $p < .05$, 95% CI = [-20.50, -1.05], but not in no window condition, b = -4.61, SE = 6.40, t (52.07) = 0.72, p = .48, 95% CI = [-16.93, 7.72]. Results indicated that, although trait rumination does not influence total reading time in natural reading, individuals with different trait rumination levels were influenced by the constrained window frames. Specifically, individuals with higher RRS scores had shorter total reading time in all conditions in which text could only be perceived through a limited window.

For positive sentences, separate mixed models in different window size conditions revealed that the RRS significantly predicted performance in the small window condition, b = -36.13, SE = 16.43, t (51.98) = 2.20, $p < .05$, 95% CI = [-67.85, -4.41] and marginally significant in the medium window condition, b = -12.54, SE = 6.91, t (51.71) = 1.81, p = .08, 95% CI = [-25.92, 0.84], but not significantly in the large window and no window condition ($ps > .24$). The results of positive sentences was quite similar to what was shown in neutral sentences, in that individuals with higher RRS scores had shorter total reading time in the most restricted conditions.

Number of Fixations

Results of the full model showed a significant effect of window size, F (3, 168.00) = 70.06, $p < .001$, and a significant two-way interaction between window size and RRS, F (3, 9687.50) = 9.19, $p < .001$ (other $Fs < 2.44$, $ps > .12$). To further analyze the two-way interaction between window size and RRS, a separate mixed model was conducted in

each window size condition. However, after controlling for current positive and negative mood, no significant effects were found in any of the window size conditions (*ts* < .001, *ps* > .99).

Reading Rate

Results of the full model showed significant effects of RRS, F (1, 54.00) = 8.66, p < .01, window size, F (3, 167.70) = 325.20, p < .001. Moreover, we found a significant two-way interaction between window size and RRS in reading rate, F (3, 9663.60) = 24.44, p < .001 (other *Fs* < 1.07, *ps* > .38).

To further analyze the two-way interaction between window size and RRS, a separate mixed model was conducted in each window size condition while controlling for positive and negative mood levels at baseline. No significant effect was found in the no window condition, b = 4.00, SE = 5.26, t (51.94) = 0.76, p = .45, 95% CI = [-6.11, 14.12], reflecting that trait rumination does not influence total reading time in natural reading. As expected, RRS significantly predicted performance in the small window condition, b = 5.47, SE = 2.64, t (51.89) = 2.08, p < .05, 95% CI = [0.40, 10.54], and also marginally significantly predicted performance in the medium window condition, b = 7.00, SE = 3.87, t (51.56) = 1.81, p = .08, 95% CI = [-0.46, 14.45], and in the large window condition, b = 9.31, SE = 4.70, t (51.88) = 1.98, p = .05, 95% CI = [0.25, 18.36]. In sum, results show that reading rate was influenced by trait rumination only when reading through various restricted windows but not in natural reading. Specifically, individuals with higher RRS scores had a faster reading rate whereas individuals with lower RRS scores had slower reading rate in the restricted window conditions.

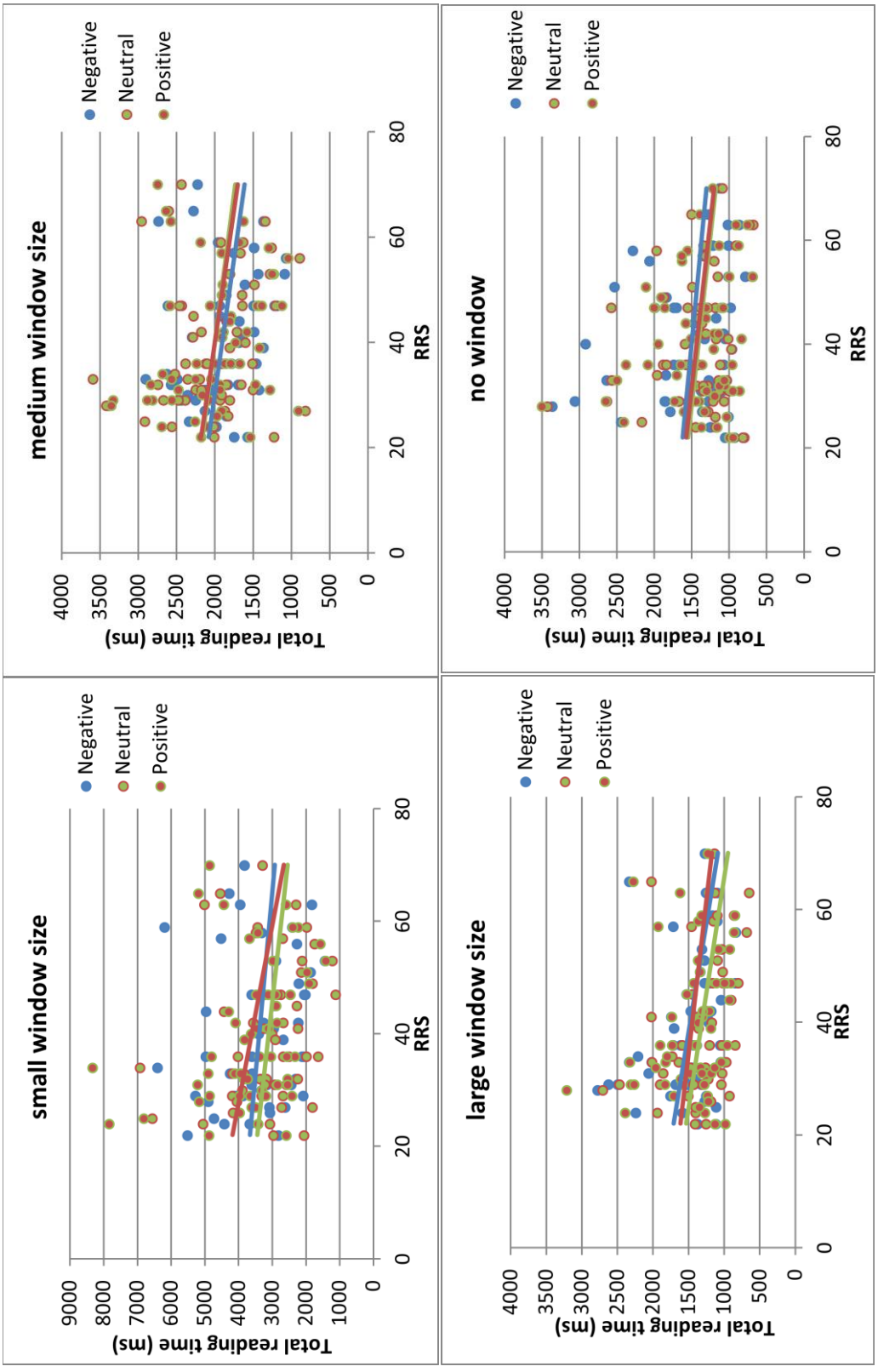

Fig.1. Total reading time of different valence of sentence as a function of the RRS score in each window size condition.

DISCUSSION

In the present study we aimed to extend the research on the relation between rumination and attentional scope while processing neutral and emotional information. To assess attentional scope, we applied a gaze-contingent moving window task which involved reading both neutral and emotional sentences. The main results indicated (1) that individuals with higher levels of trait rumination were less influenced by the constrained window frame (i.e., faster reading rate) when processing neutral, positive, and negative sentences, and (2) the total reading time of individuals with different levels of trait rumination was found to be different for neutral and positive sentences, but not for negative sentences. We discuss these effects in more detail below.

First, we found that trait rumination predicted individuals' performance when reading both neutral and emotional sentences with reduced window sizes, which was reflected by faster reading rate in individuals with higher levels of rumination. These findings are in accordance with previous research. For example, Grol et al. (2015) found that individuals with higher levels of brooding (i.e., a maladaptive subtype of rumination) presented a narrower attentional scope for neutral self-related information relative to other-related information. Recently, Fang et al. (2017) reported that, after controlling for the positive and negative mood states, individuals with high levels of trait rumination showed a faster reading rate than the ones with low levels of trait rumination when reading neutral sentences. Our findings are in line with the idea that higher levels of trait rumination are associated with a more narrow attentional scope when processing neutral information. Moreover, with the inclusion of emotional sentences, the current study showed an associated between attentional scope and trait rumination regardless of the valence of the sentences, as evidenced in the reading rate. Taken together, these findings provided supportive evidence for the prediction of the attentional scope model of rumination, which proposed that high levels of rumination would show narrow attentional scope in overall processing of information when they are in a neutral mood (Whitmer & Gotlib, 2013).

Second, we examined whether the relation between attentional scope and trait rumination would be influenced by different types of emotional sentences. The expected three-way interaction among window size, valence, and the RRS score was

only found to be significant for total sentence reading time. Further analyses revealed that high levels of trait rumination predicted faster total reading time when processing neutral and positive sentences, but this was not the case when they were reading negative sentences. These findings seem to suggest that the better performance of individuals with high levels of trait rumination when processing neutral and positive sentences through constrained window frame may be compromised or masked when processing negative sentences. However, which feature of the negative sentence influences the processing remains to be explored. In addition, it is important to note that the expected three-way interaction was only significant for total sentence reading time but not for other indexes. It has been suggested that inhibition impairments for negative information emerge when information is attended (so on an index of sustained attention: total fixation time), but not on other attention indices related to selection (number of fixations) (Everaert & Koster, 2015). Accordingly, the difference in processing of negative information may only occur during sustained attention and encoding the meaning of the information but not during the early attentional selection. However, we realize that this is a tentative conclusion based on a null result, thus future research should further examine these findings.

Our findings provide supportive evidence for the attentional scope model of rumination, but also raise some theoretical issues. On the one hand, if there is not a negative mood state, the narrower attentional scope of high ruminators would influence their overall performance on multiple types of information. On the other hand, they might still process negative information differently even if they process all types of information in a constrained manner. Future studies are needed to provide more details about these different processes in high trait ruminators. Moreover, it is also important to elucidate precisely whether high and low ruminators react differently to emotional and neutral information when they are in a neutral mood, in comparison to when they are in a negative mood state.

There are some limitations in the current study. First, we used an unselected sample in our study which may limit the generalization of the observed findings to depressed or remitted depressed patients. Nevertheless, the variability in rumination scores in the current study is comparable to the previous studies testing cognitive impairments/ processes as a function of habitual use of rumination. Second, despite our

best efforts to match the different types of sentences, there may still have been lower level differences between the different sentences types. Future research should consider constructing a well-validated sentence pool including all different types of sentence that are matched to facilitate the consistency of related studies.

CONCLUSION

In summary, the current study aimed to investigate and extend the research on the relation between rumination and attentional scope. This is the first study demonstrating that higher levels of trait rumination are associated with faster speed of reading when processing both neutral and emotional information after controlling for baseline mood. This suggests that individuals with high levels of rumination exhibit narrower attentional scope during reading. In addition, the results of total reading time showed that individuals with higher levels of trait rumination performed better when processing neutral and positive sentences under constrained window frame conditions, but this benefit was not significant anymore when processing negative sentences. These findings suggest that even though high trait ruminators use a constrained manner in processing all types of information, they may still process negative information differently compared with other types of information.

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CHAPTER 4

CAN MULTIPLE-SESSION ATTENTIONAL BREADTH TRAINING CHANGE ATTENTIONAL BREADTH AND RUMINATION?[1]

ABSTRACT

Recently, theoretical frameworks have been proposed to explain the question about what kind of people tend to use rumination more often than others. The attentional scope model of rumination suggests that individual differences in attentional breadth make them react differently to negative mood. The aim of the current research was to establish the causal direction between attentional breadth and rumination by exploring whether attentional breadth could be manipulated through these training procedures, and whether the manipulation of attentional breadth can influence rumination. This study contained one multiple-session manipulations using a combined training approach over a five day period, pre- and post-training assessment to test the direct transfer effects of training on attentional breadth construed in different measures, and a stress induction to test the effect of attentional breadth training on rumination. Our findings do not support the hypothesis that training variants of the Global-Local attentional breadth task or of the visuospatial attentional breadth task can broaden attentional breadth. Therefore, we cannot make any firm statements about the causal link between attentional breadth and rumination.

[1]Partly based on Fang, L., Hoorelbeke, K., Bruyneel, L., Notebaert, L., MacLeod, C., De Raedt, R., & Koster, E.H.W. (in press). Can training change attentional breadth? Failure to find transfer effects. *Psychological Research.* DOI: 10.1007/s00426-017-0845-y.

INTRODUCTION

Decades of research have shown that rumination, a repetitive thinking on negative mood related thoughts, is one of the most important risk factors for the onset and maintenance of depressive symptoms (Mor & Winquist, 2002; Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Several theoretical frameworks have been proposed concerning the question that what kind of people tend to use rumination more often than others (Joormann, 2010; Koster, De Lissnyder, Derakhshan, & De Raedt, 2011; Whitmer & Gotlib, 2013). According a recent attentional scope model of rumination, attentional breadth has been proposed to play an important role in explaining the repetitive nature of rumination (Whitmer & Gotlib, 2013). This model suggests that individual differences in attentional scope (or attentional breadth) make them react differently to negative mood. It argues that, when in neutral mood, individuals with narrow attentional breadth may tend to allocate their attentional resources in a more constrained manner to all kinds of information. When they feel depressed, this restricted focus would be biased by the negative mood to negative information only. In contrast, individuals with broad attentional breadth would tend to spread their attentional resources more widely in the neutral mood. This broad attentional breadth may prevent them from being stuck in the same negative thoughts repetitively. Previous studies have shown the assumed relationship between attentional breadth and rumination (Daches & Mor, 2015; Fang, Sanchez, & Koster, 2017; Grol, Hertel, Koster, & De Raedt, 2015). Given the theorized connection between attentional breadth and rumination (e.g., Whitmer & Gotlib, 2013), it is important to establish the causal nature of any observed relationship between them.

Researchers have already tried to explore the causal direction from rumination to attentional breadth. Recently, engagement in rumination has been reported to influence attentional breadth. For example, Grol et al. (2015) induced either a ruminative or problem-solving thinking style and then measured attentional breadth in an attentional breadth task including self- or other-related stimuli. They found that, relative to the problem-solving induction, people with higher levels of trait rumination who were led to ruminate showed a narrowing attentional breadth when processing

self-related stimuli, as compared to other-related stimuli. Therefore, this emotional regulation of rumination appears to causally influence attentional breadth.

In contrast, until now no research has been carried out on investigating whether the manipulation of attentional breadth can influence rumination, despite the fact that attentional breadth has been proposed to be an important cognitive factor that influences the repetitive characteristic of rumination (Whitmer & Gotlib, 2013). To test the assertion that attentional breadth causally affects rumination, it is necessary to experimentally manipulate attentional breadth and then observe its influence on rumination. In fact, several studies in the field of emotion regulation have sought to modify attentional breadth using amended variants of the Global-Local task and then to examine its impact on emotion regulation. For example, in an ERP study, Gable and Harmon-Jones (2012) used the Global-Local task to induce a global or local processing preference, on a trial-by-trial basis, before exposing participants to disgust-evoking and neutral pictures. Specifically, they asked participants first to identify either the global or the local letter presented in a visual display, and then measured the relative degree to which attention was captured by disgusting and neutral images. The results showed that when participants were induced to process global letters, rather than induced to process local letters, they showed reduced N1 amplitude towards disgust pictures, suggesting that inducing greater attentional breadth reduced processing of this negative information. Other studies have aimed to induce a more sustained change in attentional breadth using training variants of the Global-Local task. For example, Hanif et al. (2012) sought to induce differences in attentional breadth using such a modified Global-Local task. During this task, a set of hierarchical shaped stimuli were presented and participants were required to always identify either the global shape (broad training) or the local shape (narrow training). These two groups showed differences in self-regulation after exposure to this intended attentional breadth manipulation, as measured by the time spent squeezing a handgrip exerciser, which reflects individuals' efforts to regulate the negative feelings they experienced during the task. These results are consistent with the possibility that the manipulation of attentional breadth can causally influence self-regulation.

However, an important limitation of these earlier studies is that, because no measures of attentional breadth were taken after the manipulation of attentional

breadth, it remains unknown whether or not the candidate training procedures served to modify attentional breadth as intended. Unless it is first confirmed that the manipulation exerted the required impact on attentional breadth, these studies permit no strong conclusion concerning the causal influence of attentional breadth on emotion regulation. Indeed this prior literature provides no strong basis for assuming that attentional breadth can be modified using such candidate training procedures. It also is relevant to note that these previous studies only construed attentional scope in terms of global-local processing and it would be appropriate to also consider whether intended training procedure can modify attentional breadth, when this is construed in terms of visuospatial attentional scope (cf. Vanlessen, De Raedt, Koster, & Pourtois, 2016).

Current Studies

The main aim of the present research was to establish whether the manipulation of attentional breadth can influence rumination. Specifically, we examined whether attentional breadth can be changed through such intended training manipulation and, if so, whether the attentional effect of these manipulations would be evident on state rumination induced in lab. To address limitations of previous research, we used more stringent pre- and post-training assessment design, in which we directly tested whether intended attentional breadth training exerted a significant impact on attentional breadth. Moreover, we used a multiple-session, multiple training task approach in order to maximize the potential to modify attentional breadth and also to provide insight into sustained effects of attentional breadth training. Our first hypothesis was that if the attentional breadth training works, the attentional effect of these manipulations would then be evident on assessment tasks that construe attentional breadth in different ways. The second hypothesis was that the successful attentional breadth training would have impact on state rumination so that after rumination induction in lab, individuals in the broad training group would show less increase in state rumination, less decrease in positive affect and less increase in negative affect than those in the narrow training group.

METHOD

Participants

Seventy-three individuals participated in the current experiment and were randomly assigned to two training groups. The sample size was based on the consideration that one would expect at least a moderate effect size (f = .25) for such an extensive training on close transfer (on a highly similar task). This would require a total sample size at least of n = 54 (based on G-power with α = .05 and $(1-\beta)$ = .95). Here we oversampled because we expected some drop out of participants during multiple-session training procedure. Attentional breadth was assessed both before and after a 5 day procedure intended to induce differential change in attentional breadth. Participants were excluded either because their mean RT deviated more than 2.5 SDs from the sample mean during the pre-assessment (n = 2), or because their depressive symptoms met or exceeded a moderate level of depression, indicated by a BDI-II score greater than or equal to 20 (n = 6; for criteria, see Beck et al., 1996). An additional nine participants completed only the pre-training assessment, and consequently were excluded from the study. The remaining 56 participants completed the whole procedure.

Questionnaires

Depressive symptoms were assessed with the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), to ensure training groups did not differ in depression levels before training commenced. The BDI-II contains 21 items, scored on a four-point scale (0-3), and measures the occurrence and severity of depressive symptoms over the past two weeks. To ensure that training groups did not differ in either positive or negative affect, they completed the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), which is a brief measure containing 20 items that assess both positive affect (PA) and negative affect (NA). Participants completed the state version in which they had to rate the extent to which they were currently

experiencing a certain affective state on a 5-point scale. The Dutch translation of the PANAS has shown good psychometric properties (Peeters, Ponds, & Vermeeren, 1996).

In addition, state of rumination and affect were measured during post-training assessment session. State rumination was assessed with the 6-item Momentary Ruminative Self-focus Inventory (MRSI; Mor, Marchetti, & Koster, 2013), by asking participants to evaluate the degree of ruminative self-focused thinking at the moment on a 7-point scale ranging from "totally not agree" to "totally agree". In line with previous study using similar stress induction (Hoorelbeke et al., 2015; Rossi & Pourtois, 2012), participants were also asked to rate their current mood on seven 100 mm Visual Analogue Scales (VAS) ranging from "neutral" to "as much as I could imagine", including the measurement of their positive affect (i.e., "energetic", "satisfied" , and "happy"), negative affect (i.e., "angry", "tense", and "depressed"), and fatigue (McNair, Lorr, & Dropplemann, 1992).

Attentional breadth assessment and training

Both of the attentional breadth training tasks and the Global-Local assessment task were programmed using the E-PRIME 2 software package (Psychology Software Tools Inc, 2007). The visuospatial attentional breadth assessment task was programmed using Inquisit software package (Millisecond Software LLC., Seattle, WA, USA).

Assessment tasks.

Before and after the candidate attentional breadth training procedure participants' attentional breadth was assessed using the standard Global-Local Navon Letter task (Navon, 1977). There were 64 trials in total. On each trial, a black fixation cross was presented in the center of the screen for 500 ms. Then, 1 of 8 global-local Navon figures was presented. The target letter in each figure was either T or H. On each trial, only one of these two letters was presented, either as a local shape (e.g., the global letter L made up of little T's) or as a global shape (e.g., the global letter H made up of little F's). Participants had to indicate whether the presented target letter was a T or an H, as quickly and accurately as possible, by pressing one of two keys on a standard AZERTY keyboard. Thus, a local trial was the one in which the target letter was the local feature, whereas a global trial was the one in which the target letter was the global

feature. All Global-Local figures were written in upper-case letters (Times New Roman). Global letters were either global T's composed of local F's or L's, or global H's composed of local F's or L's, whereas Local letters were either local T's forming global F's or L's, local H's forming global F's or L's. In line with Hanif et al. (2012), each global letter encompassed a horizontal visual angle of 6.2° and a vertical angle of 14.3°, whereas each local letter encompassed a horizontal visual angle of 1.1° and a vertical angle of 1.4°. 50% of the trials were figures with a global target, 50% with a local target. The target remained on the screen until response. The inter-trial interval was 2000 ms.

Additionally, in order to test whether the effect of attentional breadth training would transfer to another task which measures attentional breadth in a different manner, we also delivered an established visuospatial attentional breadth assessment task (Bosmans, Braet, Koster, & De Raedt, 2009). This task was recently used for measurement of attentional breadth on self-related information in people with different levels of rumination, since rumination has been considered to be associated with self-focus attention (Grol et al., 2015). During this assessment, a self- ("ME") or other-related ("LR") word was presented 68 ms in the central area of the screen surrounded by 16 gray dots arranged in two concentric circles in one of which a black smaller circle target appeared simultaneously with the word and gray dots. Participants were required to identify the central word (ME vs. LR) as well as to localize the position of the small black target. In close trials the positions of the target were in the smaller one of the two concentric circles whereas in far trials the positions of the target were in the larger (outer) one of the two concentric circles.

Participants performed 16 practice trials and 182 test trials, during which the stimulus displays were presented for 250 ms in the first eight practice trials and then were presented 68 ms in the following eight practice trials and during all the test trials. In previous studies, as Attentional Narrowing index (ANI = accuracy of the close trials – accuracy of the far trials) has been calculated to assess the attentional breadth, and this has been shown to be an effective index that reveals variation in attentional breadth (Bosmans et al., 2009; Grol et al., 2015). Accordingly, we too used this method by computing attentional breadth using the Attentional Narrowing Index, where higher ANI scores indicate a more narrow attentional breadth and lower ANI scores indicate more broad attentional breadth.

Training tasks.

Global-Local training. In the current study, we tried to manipulate attentional breadth using a modified version of the abovementioned Global-Local task (Navon, 1977). Specifically, we exposed participants to one of the two training variants of this task, each delivering 160 trials. For the Global-Local training, people in the attentional broadening training group were instructed to only focus on and respond to the letter in the global form whereas people in the attentional narrowing training group were asked to only focus on and respond to the letter in the local form.

Visuospatial training. In addition, we developed and tested a new candidate procedure to manipulate attentional breadth. This procedure was delivered in either of two conditions designed to differentially modify attentional breadth: one intended to train broadened attention by improving attentional acuity across a wide visual angle, and the other intended to train narrowing of attention by employing the reverse contingency. Because previous research has shown that narrowed attentional breadth is related to decreasing mental well-being, here in the narrow training group, participants were only trained by improving the attentional acuity in a fixed visual angle instead of narrowing their initial attentional breadth. Participants were instructed to maintain their gaze on the center of the screen throughout the experiment. On every trial, a black fixation cross was presented in the middle of the screen. After 500 ms, while the fixation cross stayed on the screen, six letters (randomly chosen T's and H's; all uppercase, Calibri, 18) were briefly and simultaneously shown on screen for 100 ms. These six letters were positioned at different distances from the center of the screen, located on six of the 24 positions arranged on eight points around the circumference of three invisible circles. More specifically, one of the six letters was presented randomly at one of the eight positions on the circle the closest to fixation (radius circle = 50 pixels), four of the six letters were presented at the circle on medium distance from fixation (radius circle = 150 pixels) and one of the six letters was presented randomly at one of the eight positions on the circle the furthest from fixation (radius circle = 250 pixels).

Depending on the training condition, participants were required to identify either the letter closest (narrow attention group) or furthest (broad attention group) from the center of the screen. This way, participants in each of the two training groups

were required to adopt either a narrow or broad attentional focus, respectively, to optimally perform the task. In the broad attention group, whenever accuracy level on a block of trials was above 80%, the radius of the imperceptible circles increased by 20 pixels to encourage the further broadening of attention. Otherwise, the maximal eccentricities stayed at the last level, when participants' performances were below 80%. In the narrow attention group, the radius remained constant across all blocks.

The trials were presented in eight blocks of 32 training trials and four manipulation check trials, each block separated by a short break. In the manipulation check trials, a set of six different letters were presented with the same random configurations and presentation time as the training trials. However, on these trials, individuals were instructed to identify as many letters as possible. This allowed us to examine whether the letters that were best identified were those presented closest, middle distant or furthest from the center of the screen. Narrower attention will be indicated by a heightened tendency to identify the letters close to the screen center, whereas broader attention will be indicated by a more even probability of identifying letters distributed across the full breadth of the display.

On each trial of both training tasks, if the participants' response was incorrect, an error message was then presented for 500 ms. Participants were required to perform both tasks each day, and were instructed to switch the order of the two tasks across successive days. There were 160 trials in the Global-Local training and 288 trials in the visuospatial training, and each training session could be completed in around 20-30 minutes.

Stress induction

After post-training attentional breadth assessment tasks, participants received a stress induction based on the variant of a validated procedure (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Rossi & Pourtois, 2012). They obtained a fictive feedback about their post-training assessment performance compared to their baseline scores. To standardize the induction procedure, these scores were presented through an E-prime program and they were told that their post-training performance was much worse than their baseline levels, which was unexpected since they have

conducted such an intensive training procedure. After being told that the experimenter needed some time to figure out whether they should perform the assessment tasks again, participants were then left alone in the lab for three minutes, which was assumed to increase the chance for them to ruminate about what they have done during the experiment, and the consequences of this stressful situation. Before and after the stress induction, participants' state rumination and affect were measured.

Procedure

After signing informed consent, participants completed the visuospatial attentional breadth task and the Global-Local task as pre-training assessment of their attentional breadth. In line with the specific requirements of the visuospatial attentional breadth assessment task (Bosmans et al., 2009; Grol et al., 2015), participants were seated at 27 cm from a 19 inch CRT screen during pre- and post-assessment. Participants then filled out the questionnaires (BDI-II, PANAS). Subsequently, participants were randomly assigned to one of the two training groups (broad or narrow) which were scheduled to include five training sessions at home within a period of one week. During each session, participants were required to complete both the visuospatial training and the Global-Local training in random order. Every participant was given an instruction manual which included all the information and requirements regarding the home training. In the manual, they were asked to concentrate on the training tasks and to read the instruction of each task carefully. They were also asked to record the date and order in which they performed the training tasks at home. After home-training, they returned to the lab where the experimenter collected the data of the training tasks and checked the accuracy rate of each day to see whether they performed the training tasks as instructed. At the same time, participants completed the post-training assessment (i.e., cognitive transfer tasks). Following the computer tasks, they were asked to complete trait measurement and to assess their state of rumination and affect as well. Then, they received a stress induction, after which their state of rumination and affect were measured again. This experiment was approved by the local ethical committee of the Faculty of Psychology at Ghent

University, and participants were fully debriefed and reimbursed at the end of the study.

RESULTS

Participant characteristics

Participant characteristics are shown in Table 1. There were no significant differences between the two training groups on any of the self-report measures (all *t*s < 0.82) or pre-assessment task performance (all *t*s and *F*s < 1).

Table 1. *Characteristics of participants at pre-training assessment*.

	Training Group	
	Broad	Narrow
N	29	27
Age	22.38	22.48
Gender (F/M)	23/6	21/6
Questionnaires	M (SD)	M (SD)
BDI-II	6.90 (3.80)	8.26 (5.34)
PA state	34.55 (4.69)	33.81 (5.65)
NA state	17.28 (8.21)	17.85 (5.82)

Note: BDI-II, Beck Depression Inventory-II (BDI-II; Beck et al., 1996); PA and NA state, positive and negative affect (PANAS; Watson et al., 1988).

Progress on training tasks

We used Repeated Measures ANOVAs to examine the effect of time (5 sessions) on the training tasks, for each group separately. For the global-local training task we based our analyses on RTs (see Table 2 for details) since accuracy was at ceiling levels. As expected, we found a significant main effect of time for both broad training group, $F(4, 112) = 42.57$, $p < .001$, $\eta^2 = .60$ and narrow training group as well, $F(4, 104) = 41.39$, $p < .001$, $\eta^2 = .61$, which indicated that both training groups improved via training sessions. In the broad training group, the RT decreased from session 1 (M = 506, SD =

167) to session 5 (*M* = 353, *SD* = 83), and in the narrow training group the RT also decreased from session 1 (*M* = 562, *SD* = 148) to session 5 (*M* = 401, *SD* = 78).

For the attentional breadth training task, with accuracy as DV (see Table 2 for details), there was a significant main effect of time in the broad training group, $F(4, 112) = 17.44$, $p < .001$, $\eta^2 = .38$, whereas no significant main effect of time was found in the narrow training group, $F(4, 104) = 0.80$, $p = .53$, $\eta^2 = .03$. In the broad training group, participants' accuracy increased from session 1 (*M* = 79.47, *SD* = 5.32) to session 5 (*M* = 85.43, *SD* = 6.56). Note that there was no attentional breadth training in the narrow group and they had a consistently high accuracy rate across the five-days training.

Table 2. *Training progress as a function of training condition*

	Broad training group (*n* = 29)		Narrow training group (*n* = 27)	
	M	*SD*	*M*	*SD*
Global-Local Training Task (RT: ms)				
Time1	506	167	562	148
Time2	408	99	471	101
Time3	396	112	433	91
Time4	370	94	397	76
Time5	353	83	401	78
Attentional Breadth Training Task (ACC)				
Time1	79.47	5.32	94.88	5.74
Time2	82.22	6.25	96.20	3.28
Time3	82.81	5.93	96.48	2.66
Time4	83.53	5.83	97.06	2.12
Time5	85.43	6.56	94.07	14.97

We then assessed performance on the manipulation check trials as an index of attentional breadth training, by conducting a mixed ANOVA with time (5 sessions) and distance (inner vs. middle vs. outer) as within-subject factors and training group as between-subjects factor. We found a significant main effect of time, $F(4, 216) = 9.12$, $p < .001$, $\eta^2 = .14$, as well as distance, $F(2, 108) = 868.67$, $p < .001$, $\eta^2 = .94$. Importantly, we found a significant distance x group interaction, $F(2, 108) = 358.06$, $p < .001$, $\eta^2 = .87$. Further analyses showed that the broad group identified less letters in the inner circle (*M* = .49, *SD* = .15) than the narrow group (*M* = .96, *SD* = .04), $F(1, 54) = 252.24$, $p < .001$, $\eta^2 = .82$. In contrast, the broad group identified more letters in the middle circle (*M* =

.13, *SD* = .03) than the narrow group (*M* = .10, *SD* = .04), *F*(1, 54) = 14.58, *p* < .001, η^2 = .21. The broad group also detected more letters in the outer circle (*M* = .51, *SD* = .13) than the narrow group (*M* = .21, *SD* = .11), *F*(1, 54) = 93.92, *p* < .001, η^2 = .64. These results confirm that there was a differential attentional strategy required in both conditions.

Furthermore, we also tried to examine the effect of time on the attentional breadth training by using repeated measures ANOVAs with the manipulation check trials as dependent variable, for each group separately. For the inner circle, both groups did not show any significant improvement (all *Fs* < 1, *ps* > .52). For the middle circle, we found a significant increase of the accuracy both in the broad training group in which the performance improved from session 1 (*M* = .125, *SD* = .03) to session 5 (*M* = .134, *SD* = .03), *F*(4, 112) = 5.32, *p* < .001, η^2 = .16, and in the narrow group in which the performance improved from session 1 (*M* = .08, *SD* = .04) to session 5 (*M* = .11, *SD* = .04), *F*(4, 104) = 23.57, *p* < .001, η^2 = .48. Similarly, there was a significant improvement for both groups in the outer circle as well. In the broad training group, participants' accuracy increased from session 1 (*M* = .46, *SD* = .15) to session 5 (*M* = .53, *SD* = .17), *F*(4, 112) = 5.33, *p* = .001, η^2 = .16,and in the narrow training group, participants' performance improved from session 1 (*M* = .15, *SD* = .10) to session 5 (*M* = .24, *SD* = .15), *F*(4, 104) = 7.58, *p* < .001, η^2 = .23. The results of manipulation trials indicated that although there was no requirement for attentional broadening in the narrow training group, they still involved in the task actively and showed increasing improvement in their performance on middle and outer circle.

Impact of training on attentional breadth assessment

Training-related changes on the Global-Local assessment task. During data preparation, trials on which participants responded incorrectly were discarded (< 4.9%). Furthermore, trials with RTs 2.5 SDs or more above a participants' own mean RT were also excluded (< 2.8%). To determine whether the training influenced performance on the Global-Local assessment task, we conducted a mixed ANOVA with assessment time (pre- vs. post-training) and trial type (global vs. local) as within-subject factor and training group (broad vs. narrow) as a between-subjects factor on RT (see Table 2 for

details) as dependent variable. This revealed a significant main effect of assessment time, $F(1, 54) = 46.33$, $p < .001$, partial $\eta^2 = .46$, a marginally significant main effect of trial type, $F(1, 54) = 3.70$, $p = .06$, partial $\eta^2 = .06$, and a significant interaction effect between assessment time and trial type, $F(1, 54) = 8.35$, $p < .01$, partial $\eta^2 = .13$. Importantly, we found a significant interaction effect between trial type and training group, $F(1, 54) = 8.26$, $p < .01$, partial $\eta^2 = .13$, and a significant three-way interaction involving assessment time, trial type and training group, $F(1, 54) = 9.20$, $p < .01$, partial $\eta^2 = .15$ (other Fs < 0.99, $ps > .32$, partial $\eta^2 s < .02$). Further investigation of this three-way interaction revealed that its nature was as follows. Whereas the two-way interaction of trial type and time was not significant in the broad training group, $F(1, 28) = 0.01$, $p = .91$, partial $\eta^2 < .001$, this interaction was significant in the narrow training group, $F(1, 26) = 14.64$, $p < .01$, partial $\eta^2 = .36$. Specifically, in the narrow training group, there was no significant difference between the response times at pre-training assessment on the global trials ($M = 697$, $SD = 138$) and the local trials ($M = 719$, $SD = 157$), $t(26) = 1.34$, $p = .19$, $d = 0.26$. However, at post-training assessment, response times on local trials ($M = 568$, $SD = 84$) were faster than on global trials ($M = 610$, $SD = 111$), $t(26) = 3.18$, $p < .01$, $d = 0.67$, suggesting a narrowing effect of attentional breadth in the narrow training condition.

Table 3. *Reaction time (ms) as a function of training group in Global-Local assessment task*.

Time	Group	N	Global Trial		Local Trial	
			M	SD	M	SD
1	Narrow	27	624	120	635	117
	Broad	29	678	155	726	185
2	Narrow	27	697	138	719	157
	Broad	29	589	104	638	130
	Narrow	27	610	111	568	84

Training-related changes on the visuospatial attentional breadth assessment task. An average of 3.41% of the trials was discarded from further analysis due to incorrect reporting of the center word. We performed a mixed ANOVA with Time (pre- vs. post- training) and word (ME vs. LR) as within-subject factors and training group

(broad vs. narrow) as a between-subjects factor on Attentional Narrowing Index as dependent variable. We found a significant main effect of time, $F(1, 54) = 4.46$, $p < .05$, partial $\eta^2 = .08$, indicating a decrease of visuospatial attentional breadth from pre-assessment ($M = .40$, $SD = .17$) to post-assessment ($M = .45$, $SD = .17$). However, there was no group related main effect or interaction effect, Fs < 2.30, $ps > .14$, partial $\eta^2 < .04$. Therefore, the two training conditions did not exert a differential impact on visuospatial attentional breadth.

Impact of training on state rumination and mood

To examine the impact of training on state rumination and mood, we performed mixed ANOVAs with Time (pre vs. post induction) as within-subject factors and training group (broad vs. narrow) as between-subjects factor and the scores on the MRSI and VAS scales (separately) as dependent variable.

No significant results were found for state rumination, reflecting that there was no significant difference between the two training groups nor before and after rumination induction (all $Fs < 3.22$, $ps > .08$). For the VAS scale of negative affect, we only found a significant main effect of group, $F(1, 54) = 4.84$, $p < .05$, $\eta^2 = .08$, indicating that the level of negative affect across the induction was generally lower in the broad training group ($M = 16.74$, $SD = 11.57$) than in the narrow training group ($M = 24.16$, $SD = 13.65$) (all other $Fs < 1.50$, $ps > .23$).

For the VAS scale of positive affect, a significant main effect of time was found, $F(1, 54) = 22.81$, $p < .001$, partial $\eta^2 = .30$. The level of positive affect decreased after the rumination induction (pre: $M = 59.02$, $SD = 12.81$; post: $M = 51.08$, $SD = 16.74$). We also found a significant main effect of group, $F(1, 54) = 4.91$, $p < .05$, partial $\eta^2 = .08$, revealing that the level of positive affect across the rumination induction was generally higher in the broad training group ($M = 58.76$, $SD = 13.37$) than the narrow training group ($M = 51.06$, $SD = 12.57$). There was a marginally significant time x group interaction, $F(1, 54) = 3.25$, $p = .08$, $\eta^2 = .06$. To explore this interaction, separate paired samples t-test within each group yielded a significant decrease in the broad group from pre-induction ($M = 61.26$, $SD = 12.26$) to post-induction ($M = 56.25$, $SD = 15.91$), $t(28) = 2.83$, $p < .01$, $d = .56$, and also a significant decrease in the narrow group from pre-

induction (*M* = 56.60, *SD* = 13.17) to post-induction (*M* = 45.52, *SD* = 16.07), *t*(26) = 3.79, *p* = .001, *d* = .74. Furthermore, we conducted two independent sample t-tests to explore group difference before and after the induction. The result showed that there was no significant difference between the two groups before the induction, *t*(54) = 1.37, *p* = .18, *d* = .37, but a significant difference after the induction, *t*(54) = 2.51, *p* < .05, *d* = .67. The result of interaction effect and the follow-up analyses jointly indicated that, although in both groups positive affect decreased after the induction, the amplitude of decreasing was smaller in the broad group than in the narrow group.

DISCUSSION

In the current study, we conducted one multiple-session attentional breadth training with the aim of determining whether attentional breadth could be manipulated through these training procedures and whether the manipulation of attentional breadth can influence rumination. For the Global-Local assessment task, we only found a training-congruent effect for the narrow training group, whereas we failed to observe any evidence that the broad training condition served to broaden attentional breadth. For the visuospatial attentional breadth assessment task, neither the narrowing nor the broadening transfer effect was observed. In addition, after stress induction, positive affect was decreased more in the narrow training group than in the broad training group but this was not the case neither for state rumination nor for negative affect. Taken together, the current study provides no evidence that training variants of the Global-Local task and/or the visuospatial task can lead to significant increases in attentional breadth in broad training group, assessed using the Global-Local assessment task or the visuospatial assessment task. This was true regardless of an intensive multiple-session (five days) training approach that was employed. Consequently, we cannot make any firm statements about the causal link between attentional breadth and rumination. Rather, our findings indicate limited success of attentional breadth manipulations.

When reflecting on the possible explanations for the present results, we first need to consider the validity and reliability of the measures and research approach in

our study. It seems unlikely that our assessment measures were inadequate. We used the Global-Local task and a well-established visuospatial attentional breadth assessment task. The Global-Local task is the most frequently used task to assess attentional breadth (e.g., Fredrickson & Branigan, 2005) and the visuospatial attentional breadth assessment task has been used in previous research as well (e.g., Bosmans et al., 2009; Grol et al., 2015). Might it be the case that we employed inappropriate attentional breadth training procedures? We used the Global-Local training task combining with a new visuospatial training task. Importantly, the Global-Local training task has been used in previous studies that have sought to manipulate attentional breadth. This manipulation has previously shown to influence attentional bias to negative information (Gable & Harmon-Jones, 2012) and emotion regulation (Hanif et al., 2012; vanDellen et al., 2012). However, these studies typically lack manipulation check procedures, which do not allow drawing conclusions on the causal influence of attentional breadth on these far transfer measures. With regard to our novel visuospatial training task, the manipulation check trials suggest successful online manipulation of attentional breadth during training.

It is important to consider whether our failure to detect any impact of training procedures on attentional breadth could be due to insufficient power. Again this seems unlikely to be the case, if we assume a medium effect size of f = .25 (Cohen, 1988), as post-hoc power calculations confirm that our experiment showed sufficient power to detect a potential impact of the training manipulation on attentional breadth, using the G*Power 3.1.9.2 software package (Faul, Erdfelder, Buchner, & Lang, 2009). The power (1 - β) to detect the training condition x assessment time two-way interaction effect on the assessment tasks was .96. However, if we conservatively assume a small effect size of f = .10 (Cohen, 1988), the power (1 - β) to detect the interaction effect on the assessment tasks was .31. These results suggest that both assessment tasks in the current study were sufficiently powered to detect medium effects but not small effects on the measures assessing attentional breadth. Thus, power considerations add weight to our conclusion that visual attentional breadth cannot be manipulated using the modified Global-Local task or visuospatial training task.

One important characteristic that differentiates our current study from previous ones is that we measured individuals' attentional breadth pre- and post-training, which

in principle could provide stronger evidence that attentional breadth can be changed through training. However, even though the manipulation check showed that participants complied with the requirements of the training procedure, we did not find any subsequent broadening impact of these procedures on alternative measures of attentional breadth. Furthermore, after performing multiple training sessions, we only observed a decrease on the Global preference measure of attentional breadth following the narrow training condition. However, this effect was not found on the visuospatial measure of attentional breadth.

Perhaps there may not have been sufficient overlap between our training and assessment tasks. The definition of attentional breadth is often rather broad, so it is unclear which tasks provide an optimal assessment. In our study we included two different operationalizations of attentional breadth, the Global-Local and visuospatial training task, which may represent different kinds of attentional breadth. Global (or local) processing may reflect a high (or low) level of processing (Fujita, Trope, Liberman & Levin-Sagi, 2006; Hanif et al., 2012; van Dellen et al., 2012), whereas the target of the visuospatial attentional breadth training task pertains to the size of spatial perceptual attentional breadth. Though the narrowing effect in the Global-Local assessment task found may suggest a possibility that manipulation of visuospatial attention can be transferred to the global-local processing measurement, this was not the case for the broad training condition in these two experiments. Also, no transfer effect of multiple-session training was found in visuospatial assessment task. Hence, whether the effect of manipulation of one kind of attentional breadth can transfer to tasks that measure other kinds of attentional breadth should be further considered in future research.

As has been noted, some previous studies that found improvement of self-regulation after Global-Local training intended to modify attentional breadth, but failed to include any post-training assessment of attentional breadth (Hanif et al., 2012). Given the present findings, it seems unlikely that attentional breadth was actually modified in these previous studies. How then did these training procedures exert their influence on emotion regulation? One interesting possibility is that Global-Local training may instead have influenced cognitive flexibility, as greater cognitive flexibility is associated with enhanced self-regulation (Olivers & Nieuwenhuis, 2005). This was especially evident for the narrow training group, which started with global preference

and was trained to switch to local preference. Thus, the effect of Global-Local training procedures on self-regulation observed in previous research (Hanif et al., 2012) could be due to increased cognitive flexibility instead of increased attentional breadth. Future research should consider combining both pre-and post-assessment tasks that measure attentional scope and cognitive flexibility.

An alternative, but related, possibility is that the training procedures employed in these studies may have increased the flexibility of attentional breadth. According to theoretical models and empirical evidence in the visual attention domain, the field of focal attention could be seen as a single unitary focus that varies its size depending on task requirements (e.g., zoom lens model, Eriksen & St. James, 1986; Barriopedro & Botella, 1998; Muller, Bartele, Donner, Villringer, & Brandt, 2003), or as multiple foci attending to different places in a display simultaneously (e.g., Awh & Pashler, 2000; Cave, Bush, & Taylor, 2010). Notably, the mode of attentional deployment (as a changeable zoom lens or multiple foci) could even be altered within a task due to a simple change in the goals of the participants (Jefferies, Enns, & Di Lollo, 2014). Therefore, it may be that attentional breadth is highly malleable based on goals and context, such that individuals can easily modify their attentional breadth to meet task demands. In our experiments, participants were asked to keep using one dominant attentional deployment approach (i.e., using broad attentional breadth in the broad training group and narrow attentional breadth in the narrow training group), whereas in the assessment tasks no specific attentional deployment approach was required. Thus, participants may have adjusted their strategy between the training and assessment task in order to reach the optimal performance in the assessment tasks. Future research should consider using assessment tasks that do not require altering the size of attentional breadth in order to improve performance, such as the moving window task (McConkie & Rayner, 1975) which is proposed to measure perceptual attentional breadth in a natural reading context and the attention-demanding conjunction task (Hüttermann, Memmert, & Simons, 2014; Hüttermann, Memmert, Simons, & Bock, 2013) which is an interesting paradigm that could give precise information concerning the shape and size of changes in attentional breadth.

This current study is the first to our knowledge that has systematically examined whether attentional breadth can be manipulated through the application of these

candidate training procedures and whether the manipulation of attentional breadth can influence rumination. Though we did not find any broadening effect of the training, the findings of our studies have important implications for future research designed to investigate the potential causal impact of variability in attentional breadth by observing the consequences of systematically manipulating attentional breadth. The vague definition of attentional breadth, possibly overlapping with cognitive flexibility, and its flexible nature, suggests that we need to further specify whether and how attentional breadth may be involved in emotion regulation. However, the present demonstration that attentional breadth may be resistant to direct manipulation compromises the prospect of evaluating these refined theories by testing the predictions they generate concerning how induced change in attentional breadth will affect emotion regulation. Given the increasing interest in changing attentional breadth in psychopathology (Whitmer & Gotlib, 2013), instead of training people to exhibit differences in their average breadth of attention, future research could aim to increase individuals' capacity to flexibly change their attentional breadth based on the requirements of different tasks. In addition, the results of the stress induction also suggest some issues to be considered in the future rumination induction. Previous research using rumination induction procedures, participants were instructed to read a series statements which required them focus on themselves and vividly think about how they feel (Lyubomirsky & Nolen-Hoeksema, 1995; Nolen-Hoeksema & Morrow, 1993; Watkins & Teasdale, 2001). However, the nature of this induction procedure may also induce individuals to constrain their attentional breadth on purpose, which would interfere with the effect of attentional breadth training. Thus, we chose a more naturalistic induction procedure. Using similar procedure, state rumination was found to be increased using breathing focus task, and negative and positive affect was shown to be changed using VAS (Hoorelbeke et al., 2015). We used the same VAS to assess state of mood but MRSI to measure state rumination, and only the positive affect was found to be decreased after the induction. Considering the context of the stress induction in the current study was more relevant to individual's performance in the task so that the ruminative thinking may concern their bad performance and the consequences of this performance, whereas the items in the MRSI are more related to individuals' thinking about their own

life. This suggests that various assessments of state rumination are needed in order to capture different aspect of state rumination.

Several limitations in the current study should be considered. First, training effects were assessed by comparing two training groups. A no-training control group could have revealed additional information about different effects of attentional breadth training. Second, in the multiple-session training, participants conducted the training tasks at home using their own computer. This may have reduced the consistency of the training environment in ways that reduced training efficacy. Nevertheless, recent meta-analytical findings regarding cognitive training effects in the field of working memory training suggest that such training effects can be obtained regardless of whether training is administered in the lab or at home (Au, Sheehan, Tsai, Duncan, Buschkuehl, & Jaeggi, 2014). Third, although we instructed participants to always focus on the central fixation point, it is possible that they may have directed attention to other regions. However, given that the target letter was presented randomly at the eight positions on the outer circle, the best strategy for participants to adopt would be to focus on the central fixation point instead of moving eyes to some "expected" position before the appearance of the target, since the chance of the target appearing at one attended outer location is rather small (12.5%). Moreover, the target letter was presented for only 100 ms. The latency to execute a saccade exceeds this time, typically taking at least 150-175 ms (Rayner, 1998), and so our use of 100 ms target presentations precludes the possibility that participants shifted their attention to the target after its appearance.

CONCLUSION

To conclude, we investigated whether attentional breadth could be changed through experimental procedures designed to directly modify attentional breadth. We also sought to examine whether the changing attentional breadth has impact on state rumination. Our findings do not support the hypothesis that training variants of the Global-Local attentional breadth task or of the visuospatial attentional breadth task can broaden attentional breadth, as indicated by subsequent tasks that assess attentional

breadth in terms of either global-local processing preference (Global-Local assessment task) or in terms of scope of visual perception (visuospatial assessment task). This was the case after the multiple-session manipulations using a combined training approach over a five day period. Although there were some indications that training a narrowing of attentional breadth may be possible, but there was no evidence that, even with this extensive and intensive training, it was possible to induce an increase in attentional breadth. Due to the fact that visual attentional breadth was not manipulated as intended, not any firm statements about the causal link between attentional breadth and rumination can be made in the current study.

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CHAPTER 5

EXAMINING THE RELATION BETWEEN MOOD AND RUMINATION IN REMITTED DEPRESSED INDIVIDUALS: A DYNAMIC SYSTEMS ANALYSIS[1]

ABSTRACT

Cognitive theories of recurrent depression suggest that the relationship between mood and cognition is altered by previous depressive episodes. In individuals remitted from depression (RMD), this would be linked to a larger susceptibility for new depressive symptoms. This study explored whether the association between mood and rumination indeed is different between RMD and non-depressed controls relying on dynamic systems theory (DST). From DST we selected entropy, defined here as the level of instability in the dynamic patterns of mood and rumination, as main variable of interest. Daily electronic dairy measures of mood and rumination were administered in 31 RMD patients and 32 healthy controls. The results showed that mean levels of rumination and negative mood, but not entropy, were elevated in RMD individuals compared with controls. Moreover, entropy significantly predicted depressive symptoms at six months follow-up only in RMD group. These findings indicate that a higher level of instability in the dynamic patterns of momentary rumination and mood is associated with more depressive symptoms at follow-up in individuals that are more vulnerable to depression.

[1]Based on Koster, E.H.W., Fang, L., Marchetti, I., Ebner-Priemer, U., Kirsch, P., Huffziger, S., & Kuehner, C. (2015). Examining the relation between mood and rumination in remitted depressed individuals: A dynamic systems analysis. *Clinical Psychological Science, 3,* 619-627. DOI: 10.1177/2167702615578129.

INTRODUCTION

Negative mood and self-reflective thought are tightly coupled (Moberly & Watkins, 2010). Provided that negative mood is thought to signal a discrepancy between actual state and desired state (Carver & Scheier, 1998), negative mood elicits self-reflection to understand the causes of such discrepancy (Watkins, 2008). In addition, there is extensive evidence that excessive levels of self-reflection in the form of rumination, which is oftentimes defined as attending to "the causes, meanings, and consequences of depressive symptoms" (Nolen-Hoeksema, 1991, p. 569), can lead to heightened levels of negative affect (Mor & Winquist, 2002). The reciprocal relation between negative mood and rumination can explain why rumination is one of the key cognitive vulnerability factors in the onset and maintenance of depression (Nolen-Hoeksema, Lyobomrisky, & Wisco, 2008).

For many patients, depression is a recurrent disorder with data indicating high chances of new depressive episodes, even after initial remission from a first depressive episode (Kessing, Hansen, Andersen & Angst, 2004; Monroe & Harkness, 2005). In this context, it is important to understand the mechanisms that are associated with elevated risk of recurrent episodes. Despite the key role assigned to rumination in the first episode of depression, much less is known about the phenomenology of rumination in remission from depression, and its relation to recurrence of depression. Theories of recurrent depression have argued that the experience of depressive episodes can influence the link between mood and depressogenic cognition (Teasdale & Barnard, 1993). For instance, in the differential activation hypothesis (Teasdale & Barnard, 1993), it is argued that the link between negative mood and negative cognition (in the form of dysfunctional attitudes) is strengthened by having experienced one or more depressive episodes. Specifically, in individuals who have remitted from depression (RMD), negative mood reactivates negative cognition much more strongly compared with never depressed individuals. This concept is referred to as *cognitive reactivity* and there indeed is some empirical support for this notion (Segal et al., 2006) although there are also notable failures to observe this effect (Van Rijsbergen et al., 2013).

Interestingly, there is a paucity of research examining whether the relation between mood and rumination is altered according to individuals' vulnerabilities to depression. Such alteration would be conceivable as oftentimes RMD patients suffer from negative consequences of the previous depressive episode (at the social or socio-economic levels; e.g., job loss) that could give rise to rumination. Moreover, it could be that rumination is more maladaptive and is more easily triggered by negative mood in RMD patients compared with individuals with no prior history of depression. However, in conceptualizing this relationship, previous depressive episodes are not necessarily linked to linear increases in the association between rumination and negative mood. It may also be that the relationship between negative mood and rumination becomes characterized by more *variability* in both constructs and lower levels of *stability*. This could for instance be observed because of active attempts to suppress depressive thoughts which can be successful under low cognitive load but can backfire under more demanding and stressful conditions (Rude et al., 2002). Based on cognitive reactivity theory of depression one would hypothesize that the link between rumination and mood becomes tighter in RMD patients. Alternatively, it could be that the link between rumination and mood is more disrupted and less organized in RMD patients.

In order to understand the changes of rumination and negative mood we applied a dynamic systems framework to specifically examine their dynamic patterns. Dynamic systems theory (DST) posits that a dynamic system shows features that are absent or non-detectable at the level of components that make up the system (Guastello, Koopmans, & Pincus, 2008). Moreover, a dynamic system is supposed to unfold over time in a non-linear fashion, whereby each part interacts with the other(s) determining the behavior of the whole system (Sulis & Trofimova, 2001). Given its features, DST is useful to model and analyze in real time the complex interaction between mood and rumination.

In the DST framework, many possible indexes[2] can be examined. We selected *entropy* as main index. Entropy, originated from thermodynamics (Rudolf, 1865) and information theory (Shannon & Weaver, 1949), has been widely used in informatics,

[2] For example, entropy, dispersion, transition and average mean duration. In general, these indexes could describe the variability of a system from different aspects (Hollenstein, 2013).

biology and recently in psychology to describe the instability of a system (Carhart-Harris et al., 2014; Hollenstein, 2013; Hirsh, Mar, & Peterson, 2012). The level of entropy represents the level of randomness or (in)stability about the state of a dynamic system, with higher levels of entropy indicating a more unstable system. In psychopathology theories, this concept is increasingly used to allow understanding of uncertainty associated with the outcome of conflicting perception and behavior, for example, in the context of the experience of anxiety (Hirsh et al., 2012). In the present study, we use a specific type of entropy, visit entropy, which refers to the instability of transition between different states that an individual reports with regard to dimension of mood and rumination. Here higher levels of visit entropy reflect frequent and unstable changes in the dynamic patterns of momentary rumination and mood, whereas lower levels of visit entropy suggest that their fluctuations are more certain.

In our study, we investigated the dynamic patterns of rumination and negative mood in RMD vs. never-depressed individuals based on electronic daily dairy assessment of both constructs. Individuals were asked to assess their momentary mood and ruminative thinking ten times a day during two consecutive days. These two daily measurements were then used as constitutive dimensions of the dynamic system where all possible joint states were presented (otherwise known as "*state space*"; Lamey et al., 2004; Lewis, Lamey, & Douglas, 1999) and visit entropy was extracted to indicate the instability of the transitions between different states. In addition to characterizing the nature of the dynamic patterns of rumination and mood as a predictive factor of future depressive symptoms which may depend on different vulnerabilities to depression, we also examined whether the instabilities of dynamic patterns have predictive effect on future depressive symptoms and trait rumination, and whether this predictive effect is different between RMD and CTL groups. For this purpose, participants in the study were examined at a first time point and reassessed on depressive symptoms six months later.

METHOD

Participants

Data for the present study were derived from the study by Huffziger et al. (2013), in which participants were 31 individuals (age: *M* = 45.42, *SD* = 7.98; 22 female) with remitted major depressive episodes ranging from 1 to 10 (RMD group) and 32 healthy controls (age: *M* = 44.50, *SD* = 7.86; 22 female) with no present or past depressive disorder (CTL group). The RMD group and controls were matched on age, gender and education levels (see Table 1 for details).

Table 1. *Demographic and baseline characteristics for remitted depressed patients and healthy controls.*

	Group					
	RMD (*n*= 31)		CTL (*n*=32)			
	M (*SD*)/%	*Observed range*	*M* (*SD*)	*Observed range*	*Test statistic*	*p*
Age	45.42 (7.98)	27-54	44.50 (7.86)	26-55	*t*= 0.46	.647
Gender (male:female)	9:22	-	10:22	-	Chi^2= 0.04	.848
Education (% high school degree)	64.5%		62.5%		Chi^2= 0.03	.868
BDI-II T1	9.61 (8.27)	0-36	3.41 (3.93)	0-14	*t*= 3.78	< .001
MADRS T1	5.45 (4.90)	0-22	1.31 (2.33)	0-11	*t*= 4.26	< .001
N of episodes	4.13 (2.29)	1-10	-	-		
Brooding T1	10.87 (3.84)	5-19	8.13 (2.43)	5-13	*t*= 3.38	.001
Reflection T1	10.97 (3.67)	5-19	8.53 (3.31)	5-16	*t*= 2.77	.007

Note: RMD, remitted depressed group; CTL, control group; BDI-II, Beck Depression Inventory-2nd Edition; MADRS, Montgomery-Asberg Depression Rating Scale; T1, baseline measurement.

Symptom and trait measurements

Study inclusion and exclusion criteria were assessed with the Structured Clinical Interview for DSM-IV axis I disorders (SCID-I, German version Wittchen et al., 1997). Interviewer-rated depressive symptoms were assessed with the Montgomery and Asberg Depression Rating Scale (MADRS; Montgomery & Asberg, 1979). Self-rated

depressive symptoms over the past two weeks were measured with a validated German version of the Beck Depression Inventory-2nd Edition (BDI-II; Beck, Steer, & Brown, 1996; German version: Hautzinger et al., 2006). The Cronbach's αs of MADRS and BDI-II in the present samples were high (MADRS: α = .80 for RMD group and α = .73 for CTL group; BDI-II: α = .91 for RMD group and α = .78 for CTL group).

To measure trait rumination, participants completed two 5-item subscales of Response Styles Questionnaire (RSQ; Treynor et al., 2003; German version Huffziger & Kuehner, 2012), in which brooding is defined as a maladaptive and symptom-focused form of rumination, prospectively associated with negative mood and depression, whereas reflection is conceived as a less maladaptive and problem-solving-focused form of rumination (Joormann, Dkane, & Gotlib, 2006; Moberly & Watkins, 2008). In the current sample, the Cronbach's αs of brooding scale were .83 for the RMD group and .69 for the CTL group, whereas of reflection scale were .84 for the RMD group and .78 for the CTL group, indicating acceptable internal consistency.

Ambulatory assessment (AA)

After the diagnostic screening session and filling in questionnaires, participants were asked to report their momentary mood and rumination by performing the AA with ten assessments per day on two successive days. Specifically, their momentary mood was defined and evaluated with six bipolar items with three scales which have been demonstrated previously with good reliability (Wilhelm & Schoebi, 2007): valence, calmness, and energetic- arousal. Here, our interests only focused on the valence scale in which the valence of mood was assessed by rating two bipolar items ("content-discontent", "unwell-well") on a scale from 0 to 6. Scores of the "content-discontent" item were recoded, so that the total momentary valence of mood was represented from 0 to 6, in which higher scores reflect a more positive momentary mood state.

In addition, participants measured their momentary rumination state by rating two items ("At the moment, I am thinking about my problems" and "At the moment, I am thinking about my feelings") on a scale from 0 (not at all) to 7 (very much) by Moberly and Watkins (2008). The scores on these two scales were also averaged to obtain a single momentary rumination score.

State space grid analysis

The state space consisting of both momentary rumination and mood was plotted and analyzed by using GridWare 1.15a (Hollenstein, 2013). In the state space grid, we divided the scale of momentary rumination into 15 categories and also the scale of momentary mood into 13 categories in order to provide precise detail about the rates of changes (due to the reason of using average scores, the rate of changes was 0.5). Therefore, the momentary state of rumination is represented on the x-axis, ranging from 0 (no rumination) to 14 (very much rumination), and the momentary valence of mood is represented on the y-axis, ranging from 0 (negative mood) to 12 (positive mood). Each point on the grid represents a single time point where individuals provided joint information about rumination and mood. By examining the data points on the grid, we can get a time-series trajectory on different states visited by a participant (see Fig.1)[3].

To measure the instability of the system, we used *Visit Entropy* as main index (Hollenstein, 2013). Generally, the level of entropy represents the level of randomness or (in)stability about the state of a system. In the present study, computation of the entropy was based on the probability (P) of the visit of a single state, which was calculated by

$$P = \frac{Number\ of\ A\ visited}{Number\ of\ total\ visits} \quad (1)$$

where A denotes one certain joint state and visits represent one or more consecutive data points into a single state, beginning from the entry of a trajectory and ending with the exiting of it. Then, the combination of all the probabilities of every joint state was used to extract the *visit* entropy index of the whole system, i.e.

$$\text{Entropy} = \sum_{i=1}^{n} \left(\mathrm{Pi} * \ln\left(\frac{1}{\mathrm{Pi}}\right)\right) \quad (2)$$

Here the visit entropy index is formulated in such a way that higher levels of visit entropy indicate a more unstable transition among the occurring states of a system.

[3] Note that missing data were classified as an “unknown” state and considered in the analysis, as suggested by Hollenstein (2013, p. 49-50).

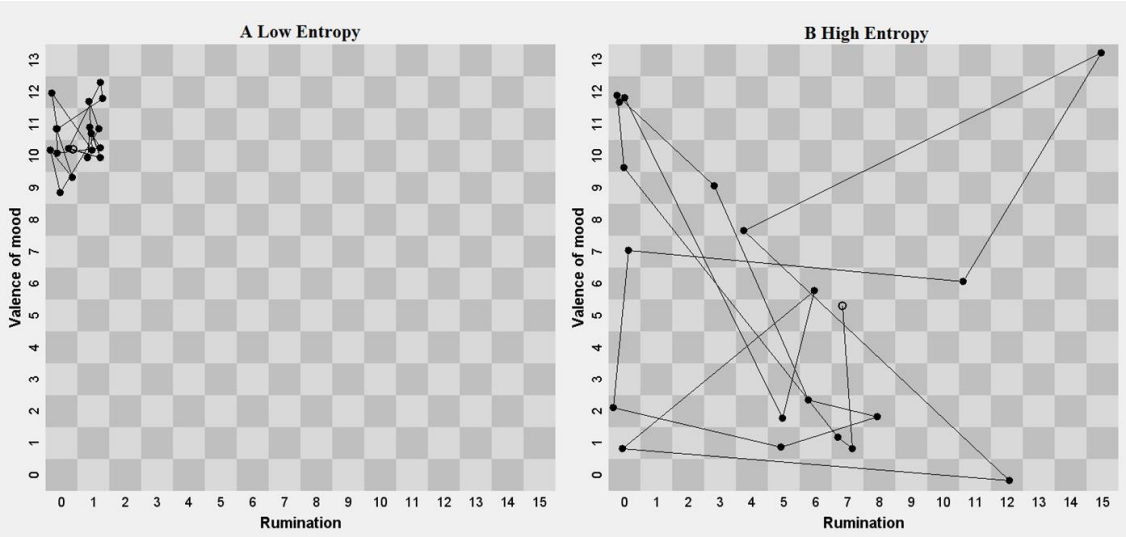

Fig.1. *State space of momentary rumination and valence of mood representing (in panel A and B respectively) two individuals in this study. Panel A is characterized by lower visit entropy than Panel B. Missing data was depicted as scores of 15 on momentary rumination and of 13 on momentary valence of mood.*

Procedure

Participants were told that they were taking part in a study on "thoughts and feelings", and were administered a telephone screening session. Following the prescreening, each participant was evaluated using the Structured Clinical Interview for DSM-IV axis I (SCID-I; Wittchen et al., 1997) and MADRS by a qualified clinical psychologist in an individual session. After that, participants received the AA instructions and completed the BDI-II and the two subscales of the RSQ (T1). Then, the AA procedure followed, and was carried out for 2 consecutive workdays during which participants had to rate their momentary mood and rumination state on a personal digital assistant (PDA, Palm Tungsten E2, Palm Inc.) after a beep. After six months (T2), participants were reassessed with the BDI-II, the MADRS, and the two subscales of the RSQ.

Data analytic plan

To investigate the dynamics in momentary mood and rumination in RMD versus healthy controls, we performed the following analyses. First, descriptive information for both groups is provided. Then, independent *t*-tests are used to test group differences in momentary rumination, mood, as well as entropy. Then, we examined the correlation between numbers of episodes, and the dynamics in rumination and mood. Finally, to investigate prediction of depressive symptoms and trait rumination six months later (T2), we conducted hierarchical regression analyses (HRAs) with BDI-II, MADRS, brooding, and reflection score at T1 in the first step and entropy in the second step as predictors, and BDI-II, MADRS, brooding and reflection score at T2 as dependent variables (separately).

RESULTS

Group characteristics

Descriptive information about both groups can be found in Table 1. RMD group and controls did not significantly differ on age and gender, but the RMD group had a significantly higher score of BDI-II, MADRS, Brooding and Reflection.

First, differences between the two groups on mean momentary rumination levels, mood and entropy were examined. The results revealed that the RMD group (M = 1.32; SD = 1.17) had marginally significant higher levels of momentary rumination than the CTL group (M = 0.82; SD = 0.87), t (61) = 1.93, p = .06, d = .49. Moreover, the mood ratings were significantly less positive in the RMD group (M= 3.97, SD = 1.01) compared with the CTL group (M = 4.68, SD = 1.15), t (61) = 2.60, p = .01, d = .66. However, groups did not differ significantly on entropy, RMD group (M= 2.26, SD = .44), CTL group (M= 2.04, SD= .66), t < 1.7.

In a next step, the impact of previous episodes on the dynamic pattern of mood and rumination was investigated by inspecting correlations between numbers of episodes, entropy, momentary state measures in the RMD group. The results showed that the number of episodes was not correlated with momentary rumination (r_s = .27, p

= .15), momentary valence (r_s = -.01, p = .97), as well as entropy (r_s = .23, p = .23)[4]. In addition, we checked for a possible difference in the association between momentary rumination and mood in the RMD versus the CTL group. Fisher's Z test indicated that the difference in correlations was not statistically significant (RMD: r_s= -.61, CTL: r_s = -.75; z< 1.10, p = .32) (Preacher, 2002).

Predicting recurrent depressive symptoms

In order to examine whether alterations in the dynamic pattern of rumination and mood is of relevance for the clinical phenomenon of recurrent depression, we investigated prediction of depressive symptoms and trait rumination six months later (time 2) based on symptom- and trait scores at time1 and entropy. Separate HRAs were conducted for predicting depression and rumination scores in the RMD and CTL group where in a first step entered relevant baseline questionnaire scores (e.g., time 1 BDI-II) and included entropy in the second step to examine whether entropy has incremental predictive value. The results of the HRA on BDI-II scores at time 2 are presented in Table 2. BDI-II scores at time 1 significantly predicted BDI-II scores at time 2 in both RMD and control group. Interestingly, after controlling for BDI-II scores at time 1, entropy in the RMD group explained an additional 16% of variance of BDI-II scores at time 2. In the CTL group, no significant associations were found with entropy.

To examine whether similar effects are obtained with the interview-based clinical assessment, we performed a similar HRA using the MADRS scores. Results of this HRA are presented in Table 2. In the RMD group, MADRS scores at time 1 and entropy were found to significantly predict MADRS scores at time 2. Importantly we observed a tendency that entropy could explained additional variance (5%) of depressive symptoms as assessed at time 2, whereas no significant contribution of entropy was found in the CLT group.

[4] Note that when we used 1 as the unit of change, entropy was significantly correlated with the number of episode in RMD group, r = 42, p = .02. It also significantly predicted the BDI-II and MADRS at time 2, similarly as what we have present in the article. Here, we reported the entropy obtained from the state space grid with 0.5 as the unit of change, since it is supposed to provide a more precise detail of average changes.

The HRA for brooding scores at time 2 is shown in Table 3. In both groups, brooding scores at time 1 included in the first step of the HRA significantly predicted brooding scores at time 2. When entropy was added in the second step, there's a tendency that it added to the prediction of brooding in both the RMD group (i.e., 5%) and the CTL group (i.e., 7%). In line with previous results, higher levels of brooding at time 1 and higher levels of entropy are related to higher levels of brooding at time 2.

The results of the HRA on reflection at time 2 are presented in Table 3. In both RMD and control groups, reflection scores at time 1 were found to be significantly predictive of reflection scores at time 2. However, after entering entropy in the second step, it significantly explained additional variance (9%) of reflection scores at time 2 only in the CTL group.

Note that we also conducted HRAs examining whether mean levels of daily reported rumination and negative mood had a similar predictive effect in RMD individuals and, as shown in Supplementary material (Table S2 and S3), this was not the case.

Table 2. *Hierarchical regression analysis predicting BDI-II T2 and MADRS T2 (separately) in two groups.*

Steps	*Predictors*	*ΔR2*	*df*	*B*
BDI-II				
RMD group				
Step 1		.16*	(1,29)	
	BDI-II T1			.40*
Step 2		.16*	(1,28)	
	BDI-II T1			.23
	Entropy			.43*
CTL group				
Step 1		.33**	(1,28)	
	BDI-II T1			.57**
Step 2		.03	(1,27)	
	BDI-II T1			.50**
	Entropy			.19
MADRS				
RMD group				
Step 1		.45***	(1,29)	
	MADRS T1			.67***
Step 2		.05†	(1,28)	
	MADRS T1			.56**
	Entropy			.25†
CTL group				
Step 1		.23**	(1,28)	
	MADRS T1			.48**
Step 2		.02	(1,27)	
	MADRS T1			.44*
	Entropy			.15

Note: †p< .1; *p< .05; **p< .01; ***p< .001. RMD, remitted depressed group; CTL, control group; BDI-II, Beck Depression Inventory-2nd Edition; MADRS, Montgomery-Asberg Depression Rating Scale; T1, baseline measurement; T2, six months follow-up.

Table 3. *Hierarchical regression analysis predicting brooding T2 and reflection T2 (separately) in two groups.*

Steps	*Predictors*	*ΔR2*	*df*	*β*
Brooding				
RMD group				
Step 1		.49***	(1,29)	
	Brooding T1			.70***
Step 2		.05†	(1,28)	
	Brooding T1			.67***
	Entropy			.22†
CTL group				
Step 1		.35**	(1,28)	
	Brooding T1			.59**
Step 2		.07†	(1,27)	
	Brooding T1			.51**
	Entropy			.28†
Reflection				
RMD group				
Step 1		.56***	(1,29)	
	Reflection T1			.75***
Step 2		.00	(1,28)	
	Reflection T1			.72***
	Entropy			.08
CTL group				
Step 1		.34**	(1,28)	
	Reflection T1			.58**
Step 2		.09*	(1,27)	
	Reflection T1			.48**
	Entropy			.32*

Note: †p< .1; *p< .05; **p< .01; ***p< .001. RMD, remitted depressed group; CTL, control group; T1, baseline measurement; T2, six months follow-up.

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DISCUSSION

The aim of the present study was to examine whether the instability of the dynamic pattern between mood and rumination differs between individuals with RMD and never depressed individuals. We also examined whether the instabilities of dynamic patterns have predictive effect on future depressive symptoms and trait rumination, and whether this predictive effect changes according to individuals' vulnerability to depression. Based on cognitive theories of depression, one could hypothesize that the link between rumination and mood becomes tighter in remitted depressed patients (Teasdale & Barnard, 1993). Alternatively, it could be that the link between rumination and mood is more disrupted and less organized in RMD patients. In order to test these opposite views, we applied dynamic systems theory and used a specific index to assess instability, which is *visit entropy*. The main findings of our study are that (1) at the group level, RMD and CTL do not have different levels of entropy; and (2) entropy adds significantly to the prediction of future depressive symptoms in RMD but not in CTL individuals. These findings are discussed below.

The first issue to be considered is that no significant difference between RMD patients and CTL group were found in the correlation between mood and rumination as well as in the dynamic relation of these two constructs, i.e., the levels of the entropy. These findings are not in line with the idea of cognitive reactivity where one would expect a tighter link between mood and negative cognition (see Scher, Ingram, & Segal, 2005) but are in line with recent studies that failed to detect higher cognitive reactivity in RMD (Van Rijsbergen et al., 2013; Wichers, Geschwind, & Peeters, 2010). However, it should be noted that cognitive reactivity is mainly focused on dysfunctional attitudes and not rumination.

More importantly, at the group level we found no differences in entropy between RMD and CTL. This suggests that the clinical status of previous depression does not always lead to a more disorganized relation between mood and rumination. However, previous research has suggested that different populations may have different optimal levels of entropy (Cunningham, Dunfield, Stillman, 2013). It implies that even though the average level of entropy was not significantly different between the RMD and CTL groups, it can still play different roles when associated with future

depressive symptoms according to individuals' different vulnerabilities to depression. In this respect, the prospective part of the current study is of crucial importance.

A key finding of our study is that the pattern characteristics of the dynamics of mood and rumination play an important role in predicting future depressive symptoms and levels of rumination. Entropy significantly predicted depressive symptoms assessed by self-report BDI-II in six months later in RMD group, even when controlling for depressive symptoms at time 1. Moreover, clinical assessment with the MADRS interview confirmed this result. It is noteworthy that we also conducted regression analyses examining whether mean levels of daily reported rumination and negative mood had a similar predictive effect and, as shown in Supplementary material (Table S2 and S3), this was not the case. Thus, these results suggest that entropy, the level of instability between mood and rumination, plays a specific role as a vulnerability factor. Interestingly, this finding is echoed in the prediction of brooding (but not reflection) which is considered the more depressogenic type of rumination.

Our study is among the first to integrate ambulatory assessment and the dynamic system theory in relation to psychopathology. Given the specific role of entropy in predicting future depressive symptoms, DST framework could be used to detect and measure the subtle alterations in RMD patients' dynamic patterns of mood and cognition. This implies that both at the theoretical and clinical level, instead of focusing on mean levels of rumination and mood, a more detailed analysis of the relation between mood and cognition could be a promising way to improve our understanding of cognitive vulnerability in recurrent depression. Here, a key theoretical question is why higher levels of entropy were associated with higher levels of depressive symptoms at six months follow-up in the RMD group. We can speculate that the more instability in RMD individuals may be potentially caused by that they sometimes ruminate in a positive mood. Alternatively, thought control strategies that only occasionally work (i.e., initial suppression of negative thought leading to subsequently increases in negative thought, see Rude et al., 2002) could be another reason for maladaptive effect of the heightened entropy in RMD individuals.

Provided that the current study is among the first to use DST indices in predicting depression scores, there are several issues that need further consideration in follow-up research. First, given the limited sample size, only two factors could be

included as predictors of future depression symptoms and trait rumination. Thus, it is possible that with more predictors, more sophisticated hierarchical regression analyses could be applied. Second, given that the present daily assessments were conducted during a relatively short time period where participants were mostly in a neutral or positive mood state, the amount of variability observed in mood and rumination might be larger in more prolonged assessment.

CONCLUSION

In sum, we consider the DST framework as a useful approach for examining the dynamic patterns of momentary mood and rumination in daily life. We found that entropy predicted future depressive symptoms and maladaptive brooding in remitted depressed individuals. Our results indicate that entropy, which maps the ongoing dynamic process of mood and rumination, can be considered as one of the vulnerability factors that predict future depressive symptoms.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Author Contributions

E.K, and I.M. developed the study concept. C.K., S.H., U.E-P., & P.K. collected the data. E.K., L.F. & I.M. analysed and interpreted the data. E.K. & L.F. drafted the manuscript, and I.M. & C.K. provided critical revisions. All authors approved the final version of the manuscript before submission.

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SUPPLEMENTARY TABLES

S1: Correlations (Spearman) between BDI-II scores, MADRS scores, brooding scores, reflection scores, momentary measurements and Entropy in RMD and CTL group.

S2: Hierarchical regression analysis predicting BDI-II scores T2 and MADRS scores T2 (separately) in two groups (including BDI-II scores/ MADRS scores T1 as step 1, and mean scores of momentary rumination and mood as step 2 in HRA).

S3: Hierarchical regression analysis predicting brooding T2 and reflection T2 (separately) in two groups (including brooding/ reflection T1 as step 1, and mean scores of momentary rumination and mood as step 2 in HRA).

Table S1. *Correlations (Spearman) of BDI-II scores, MADRS scores, Brooding scores, Reflection scores, momentary measurement and Entropy (correlations above diagonal and in bold font refer to the RMD, correlations below the diagonal to the CTL)*

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1.BDI-II T1		**.44***	**.73*****	**.35**†	**.48****	**.45***	**.39***	**.29**	**.59*****	**-.40***	**.47****
2.BDI-II T2	.58**		**.58****	**.84*****	**.32**†	**.64*****	**.53****	**.52****	**.58****	**-.38***	**.73*****
3.MADRS T1	.39*	.57**		**.55****	**.22**	**.27**	**.33**†	**.15**	**.54****	**-.55****	**.46****
4.MADRS T2	.38*	.75***	.62***		**.10**	**.51****	**.36***	**.45***	**.59*****	**-.46****	**.64*****
5.Brooding T1	.44*	.59**	.44*	.30		**.75*****	**.58****	**.31**†	**.19**	**.02**	**.31**†
6.Brooding T2	.27	.58**	.50**	.44*	.58**		**.62*****	**.70*****	**.41***	**-.11**	**.46***
7.Reflection T1	.40*	.31†	.24	.26	.35*	-.06		**.72*****	**.56****	**-.11**	**.47****
8.Reflection T2	.38*	.47**	.30	.28	.39*	.34†	.61***		**.54****	**-.03**	**.39***
9.Momentary Rumination	.50**	.42*	.37*	.28	.40*	.44*	.31†	.57**		**-.61*****	**.66*****
10.Momentary Mood	-.50**	-.44*	-.54**	-.37*	-.47**	-.51**	-.31†	-.36†	-.75***		**-.50****
11.Entropy	.41*	.36†	.38*	.27	.38*	.43*	.28	.48**	.92***	-.86***	

Note: *p< .05; **p< .01; ***p< .001. RMD, remitted depressed group; CTL, control group; BDI-II, Beck Depression Inventory-Revised; MADRS, Montgomery-Asberg Depression Rating Scale; T1, baseline measurement; T2, six months follow-up.

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Table S2. *Hierarchical regression analysis predicting BDI-II T2 and MADRS T2 in remitted depressed and controls.*

Steps	*Predictors*	*ΔR2*	*df*	*B*
BDI-II				
RMD group				
Step 1		.16*	(1,29)	
	BDI-II T1			.40*
Step 2		.11	(2,27)	
	BDI-II T1			.08
	Momentary Rumination			.41
	Momentary Mood			-.07
CTL group				
Step 1		.33**	(1,28)	
	BDI-II T1			.57**
Step 2		.09	(2,26)	
	BDI-II T1			.41*
	Momentary Rumination			.45
	Momentary Mood			.13
MADRS				
RMD group				
Step 1		.45***	(1,29)	
	MADRS T1			.67***
Step 2		.03	(2,27)	
	MADRS T1			.53**
	Momentary Rumination			.20
	Momentary Mood			- .03
CTL group				
Step 1		.23**	(1,28)	
	MADRS T1			.48**
Step 2		.05	(2,26)	
	MADRS T1			.47*
	Momentary Rumination			.47
	Momentary Mood			.34

Note: *p< .05; **p< .01; ***p< .001. RMD, remitted depressed group; CTL, control group; BDI-II, Beck Depression Inventory-Revised; MADRS, Montgomery-Asberg Depression Rating Scale; T1, baseline measurement; T2, six months follow-up.

.

Table S3. *Hierarchical regression analysis predicting brooding T2 and reflection T2 in remitted depressed and controls.*

Steps	*Predictors*	*ΔR2*	*df*	*B*
Brooding				
RMD group				
Step 1		.49***	(1,29)	
	Brooding T1			.70***
Step 2		.09	(2,27)	
	Brooding T1			.65***
	Momentary Rumination			.33*
	Momentary Mood			.06
CTL group				
Step 1		.35**	(1,28)	
	Brooding T1			.59**
Step 2		.07	(2,26)	
	Brooding T1			.45*
	Momentary Rumination			.23
	Momentary Mood			- .07
Reflection				
RMD group				
Step 1		.56***	(1,29)	
	Reflection T1			.75***
Step 2		.10*	(2,27)	
	Reflection T1			.55***
	Momentary Rumination			.47**
	Momentary Mood			.28
CTL group				
Step 1		.34**	(1,28)	
	Reflection T1			.58**
Step 2		.13	(2,26)	
	Reflection T1			.47**
	Momentary Rumination			.70*
	Momentary Mood			.42

Note: *p< .05; **p< .01; ***p< .001. RMD, remitted depressed group; CTL, control group; T1, baseline measurement; T2, six months follow-up.

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CHAPTER 6

DO DAILY DYNAMICS IN RUMINATION AND AFFECT PREDICT DEPRESSIVE SYMPTOMS AND TRAIT RUMINATION? AN EXPERIENCE SAMPLING STUDY[1]

ABSTRACT

Rumination has been shown to prospectively predict the onset of depression. However, it is unclear whether the dynamic patterns of rumination and affect in daily life can also predict future depressive symptoms. The present study examined whether the structure of dynamic patterns in rumination and affect, expressed using entropy, could prospectively predict depressive symptoms and trait rumination in an unselected sample (*n* = 63). Momentary rumination and affect were assessed eight times per day within seven days. Additionally, depressive symptoms and trait rumination were measured at the beginning of the experiment and at six weeks follow-up. The results showed that trait rumination and depressive symptoms at six weeks follow-up were predicted by entropy. Our findings suggest that the structure of dynamic patterns of momentary rumination and affect contributes to the development of depression and trait rumination.

[1]Based on Fang, L., Marchetti, I., Hoorelbeke, K., & Koster, E.H.W. (2017). Do daily dynamics in rumination and affect predict depressive symptoms and trait rumination? An experience sampling study. Manuscript submitted to publication.

INTRODUCTION

Decades of research have shown that rumination forms one of the most important cognitive vulnerability factors for the onset and maintenance of depressive episodes (for reviews, see Mor & Winquist, 2002; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). According to the Response styles theory of depression, rumination can be conceived as a thinking style that repetitively focuses on the implications, causes and meanings of one's feelings and problems (Nolen-Hoeksema, 1991). In fact, previous studies have consistently shown that rumination has detrimental influence on affect (Watkins, 2008), which can prolong negative mood and may then cause the development of depressive episodes (Ciesla & Roberts, 2007). Although these findings suggest a prospective effect of ongoing interactions between rumination and affect in daily life on depressive symptomatology, few studies have directly examined whether the dynamics in momentary rumination and affect could predict development of depressive symptoms. Therefore, a better understanding of daily dynamics in rumination and affect, and their contributions would be important in the prevention and treatment of depression.

Rumination and affect in daily life

Although mostly treated as a stable trait-like construct (Nolen-Hoeksema & Davis, 1999), ruminative thought in daily life is an ongoing dynamic process (Kasch, Klein, & Lara, 2001), and can be measured accordingly through experience sampling methods (Kircanski, Thompson, Sorenson, Sherdell, & Gotlib, 2015; Moberly & Watkins, 2008). A large number of experience sampling studies have provided evidence that momentary rumination is often followed by exacerbation of negative affect (Hoorelbeke, Koster, Demeyer, Loeys, & Vanderhasselt, 2016; Moberly & Watkins, 2008; Takano & Tanno, 2011) and/or decreases in positive affect (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Hoorelbeke et al., 2016; Huffziger, Ebner-Priemer, Zamoscik, Reinhard, Kirsch, & Kuehner, 2013). It should be noted that in daily life, however, not only does rumination have an impact on affect, but affect also influences

rumination. Previous research has shown that negative affect can predict subsequent rumination (Hoorelbeke et al., 2016; Moberly & Watkins, 2008).

The nature of the interplay between rumination and affect in daily life may be an important factor in predicting depressive symptoms. In a recent experience sampling study, Pasyugina, Koval, De Leersnyder, Mesquita, and Kuppens (2015) examined the predictive value of the average level of momentary rumination and its influence on momentary negative affect to future depression. For this purpose, participants' levels of momentary rumination were assessed between moment t and t-1, whereas momentary affect was assessed at moment t. They found that changes in depression ratings over a week were predicted by the average level of momentary rumination. In contrast, the influence of momentary rumination on negative affect did not predict changes in depression. These results indicate that a close examination of the relation between affect and rumination may be crucial in understanding predictive effects on depressive symptoms.

Dynamic systems, state space and entropy

The complex relationship between two variables interacting in a certain context (a system) can be investigated in many ways, but a particularly interesting perspective is offered by Dynamic System Theory (DST; Hollenstein, 2013; Lewis & Granic, 2000; Thelen & Smith, 1998). In fact, the DST suggests that a whole system, containing elements (e.g., rumination and affect in the current study) that covary over time, shows specific characteristics that are not detectable at the level of its components (Thelen, 1995). In other words, investigating the structure of the whole system, that represents how the whole system changes over time, may reveal features that may be overlooked when only the content is considered. For example, previous research has shown that the structure of dynamic emotional states in parent-child interaction plays an important role in predicting psychopathology above and beyond the content of these emotional interactions (for a review, see Hollenstein, Lichtwarck-Aschoff, & Potworowski, 2013). Therefore, in our current study, we sought to further investigate the influence of rumination and affect on depression by exploring the structure of their daily dynamics.

From the DST perspective, in order to adequately investigate a system, it is necessary to first represent all the possible states of the system (also known as state space; Heath, 2012; Hollenstein, 2013; Lamey, Hollenstein, Lewis, & Granic, 2004) and then display the trajectory of states that the system takes over time. By doing so, different types of information can be attained, such as the content (e.g., the mean level of each variable) as well as the structure (e.g., variability) of the system. Among various structure indices, entropy is one of the most frequently used metrics to investigate the structural variability of the system, as it captures the amount of information generated as the system changes (Mitchell, 2009; Shannon & Weaver, 1949; Young, 2003). Importantly, previous study suggests that entropy forms the most representative index when compared to similar measures for system variability (Sravish, Tronick, Hollenstein, & Beeghly, 2013). In this context, a system that has a less stable structure produces higher amounts of new information (i.e., multiple states are visited over time), which would be reflected by higher levels of entropy (Mainzer, 2007).

Recently, Koster et al. (2015) explored whether there was different dynamics between remitted depressive patients and healthy controls. They found that visit entropy, a specific type of entropy which depicts the variability of the transitions between different states in the dynamic pattern between momentary affect and rumination, predicted depressive symptoms at six months follow-up only in remitted depressed patients. Interestingly, entropy remained a significant predictor of future depressive symptomatology after considering the contribution of depressive symptoms at baseline. These findings indicate that the structure of the dynamic pattern between momentary rumination and affect, operationalized by visit entropy, may have a particular predictive effect on depressive symptomatology. However, the healthy controls in this study (Huffziger et al., 2013; Koster et al., 2015) were selected strictly (i.e., never depressed individuals) as a comparative group to remitted depressive group, which thus had a relatively low depression scores at baseline (BDI-II: M = 3.41; SD = 3.93; range: 0-14). It remains unclear whether the dynamics of rumination and affect, in a more general population, influence future depressive symptoms. Therefore, in our study, we used visit entropy as the index that provides information about the structure of the dynamics between momentary rumination and momentary affect in an unselected sample.

Furthermore, it has been assumed that a dynamic system is multi-levelled, with components at different levels interacting with each other (Hollenstein et al., 2013; Wichers, 2014). For example, components at lower levels can build or form a new component at a higher level after a certain amount of time. This new higher level component can then influence or constrain the change of the lower-level components. Consistent with this view, it would be worth examining whether the dynamics of components at lower levels in the dynamic system, that is momentary rumination and affect, can predict rumination at a higher level (i.e., trait rumination).

The present study

In the present study, we tested the predictive potential of the dynamic structure of rumination and affect in daily life for depressive symptoms and trait rumination at six weeks follow-up. Specifically, we measured trait rumination and depressive symptomatology at baseline and at six weeks follow-up, and tracked momentary changes of ruminative thinking and affect in daily life using experience sampling methodology during one week following the baseline assessment. According to previous study (Koster et al., 2015), we investigated the structure of momentary rumination and affect by means of a state space grid (Hollenstein, 2013). Our first hypothesis, based on previous research (Koster et al., 2015; Wichers, 2014), was that entropy would prospectively predict changes in depressive symptoms. Second, to examine whether the momentary changes of ruminative thinking and affect could give rise to changes in trait measurement (Hollenstein et al., 2013), we hypothesized that the structure of the system (i.e., entropy) of rumination and affect in daily life could predict changes in the follow-up trait rumination measurement.

METHOD

Participants

Sixty-nine undergraduate students from Ghent University enrolled at baseline. In order to avoid additional costs of participation to the experience sampling study, all

participants were required to possess a smartphone with a monthly data plan. The study was approved by the local ethics committee of Ghent University.

Measures

Symptom and trait measurements. Depressive symptoms were measured with the 21-item Beck Depression Inventory (BDI-II-NL; Beck, Steer, & Brown, 1996; Van der Does, 2002). Participants were asked to rate each item on a 4-point scale from 0 to 3 with regard to the occurrence and severity of depressive symptoms over the past two weeks (BDI-II at time 1: α = .79; at time 2: α = .84). Trait rumination was measured with the 22-item Ruminative Response Scale (RRS-NL; Nolen-Hoeksema & Morrow, 1991; Raes, Hermans, & Eelen, 2003; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Participants were asked to rate on a 4-point scale how they typically respond when they are feeling depressed (RRS at time 1: α = .90; at time 2: α = .91).

Daily assessment. Participants were asked to report their momentary affect and rumination with eight assessments per day within seven days. We used a stratified random sampling approach, whereby each day between 10:00 a.m. and 10:00 p.m. was divided into eight equal intervals and a signal was sent at a random time point in each interval. At every assessment point, participants received a text message via SurveySignal containing a link which directed them to Limesurvey for the online measurements of momentary rumination and affect. For momentary rumination, participants were asked to indicate their ruminative self-focus the moment just before receiving the signal on a scale from 0 (not at all) to 7 (very much). In line with previous studies (Moberly & Watkins, 2008; Hoorelbeke et al., 2016; Ruscio et al., 2015; Takano & Tannon, 2011), we used the average score of two items to assess their momentary ruminative self-focus (“Focused on feelings” and “Focused on problems”). Momentary affect experienced just before receiving the signal was assessed by rating two bipolar items (discontent-content, unwell-well) on a scale from 0 to 6 (Huffziger et al., 2013). The average score of these two items was used as the indicator of momentary affect. Here, higher scores reflect a more positive momentary affect state. The items were randomly presented between and within the momentary measurement of rumination

and affect. All text messages were delivered using SurveySignal software (Hofmann & Patel, 2015) and paid by researchers using SurveySignal credits.

State space grid analysis. The dynamic structure of momentary rumination and affect was plotted in a state space grid and analyzed with GridWare 1.15a (Hollenstein, 2013; Lamey et al., 2004). In line with previous study (Koster et al., 2015), 0.5 was used as the unit of change which results in 15 units for the rumination scale and 13 units for the affect scale (see Fig. 1). For maximum retention of the original information, we added 1 unit as unknown state in each scale (i.e., state 15 in rumination scale and state 13 in affect scale) for missing data (cf. Hollenstein, 2013). The momentary state of rumination is presented on the x-axis, ranging from 0 (no rumination) to 14 (very much rumination) whereas momentary affect is presented on the y-axis, ranging from 0 (negative affect) to 12 (positive affect). Each point in the state space grid represents the current state of rumination and affect at that time point. Combining all the points in the state space grid reveals how ruminative thinking and affect changed over time.

To measure the structural variability of the transitions between different states, we used *Visit Entropy* as our main index (Hollenstein, 2013). One 'visit' here refers to one or more consecutive points that are grouped into a single state, from the first point entering this state until the last point that leaves this state. According to Hollenstein (2013), entropy of the whole system was calculated by,

$$\text{Entropy} = \sum_{i=1}^{n} \left(\mathrm{P}_i * \ln\left(\frac{1}{\mathrm{P}_i}\right)\right) \qquad (1)$$

where n denotes the number of possible states and P denotes the probability of the visit of a single state over all the states, which was calculated by

$$\mathrm{P} = \frac{Number\ of\ A\ visited}{Number\ of\ total\ visits} \qquad (2)$$

where A denotes a certain joint state. Based on the equations, higher levels of entropy indicate a more unpredictable transition among different states of a system.

Procedure

After signing informed consent, participants completed the BDI-II and RRS as baseline measures of depressive symptomatology and trait rumination. Next, participants were registered in SurveySignal and given the daily measurement

instructions. The daily measurement started one day after the registration and contained eight assessments a day over a period of seven days. Signals were sent between 10 a.m. and 10 p.m., during which participants had to rate their momentary affect and rumination. At six weeks follow-up, depressive symptoms and trait rumination were reassessed using the BDI-II and RRS, after which participants received a debriefing and were reimbursed for their participation.

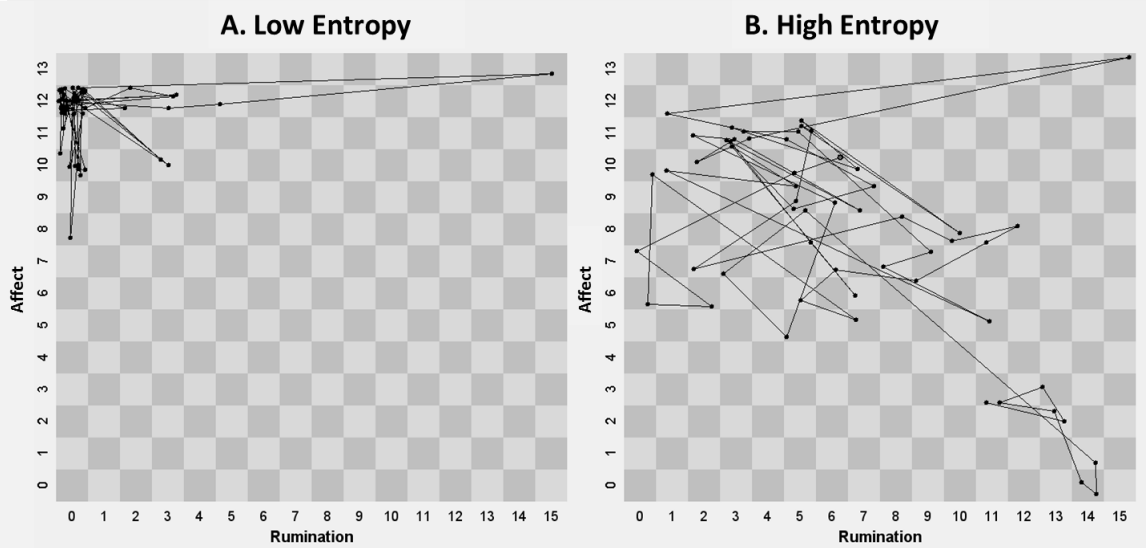

Fig.1. *State space of momentary rumination and affect illustrating two participants in the current study. Panel A displays lower visit entropy than Panel B. Missing data was depicted as scores of 15 on momentary rumination and of 13 on momentary affect*.

RESULTS

Group characteristics

Sixty-nine participants completed the baseline assessment of depressive symptomatology and trait rumination. One participant did not attend the follow-up assessment. Four participants were excluded due to poor compliance. One outlier was excluded because its standardized residual was larger than 3.0 in regression analyses. The remaining 63 participants (age: *M* = 18.48, *SD* = 1.27; 51 female) were highly compliant with the daily measurement procedure (response rate: *M* = 91.16%; *SD* =

7.54%; *range* = 68%-100%). Descriptive information concerning age, gender and measurements of depressive symptomatology and trait rumination can be found in Table 1. Our sample showed sufficient variation in depressive symptoms and trait rumination.

Table1. *Demographic characteristics (N = 63)*.

	Mean	*SD*	*Range*
Age	18.48	1.27	17-22
Gender (female:male)	51:12		
BDI-II T1	10.29	5.78	0-27
RRS T1	41.11	10.90	23-68
BDI-II T2	9.49	5.90	1-28
RRS T2	38.17	10.55	23-68

Note: BDI-II, Beck Depression Inventory-II; RRS, Ruminative Response Scale; T1, baseline measurement; T2, six weeks follow-up.

Zero-order correlations

The mean level of momentary rumination was 1.90 (*SD* = 1.04; *range* = 0.22-4.81) and the mean level of momentary affect was 4.11 (*SD* = 0.54; *range* = 2.94-5.77). First, we examined the relationship between momentary affect and rumination. The result showed that the mean level of momentary affect was negatively correlated with momentary rumination (r = -.31, p = .02), indicating that individuals reporting less positive affect tend to ruminate more in daily life. We then checked the relationship between measures for momentary affect and rumination, and trait measures at baseline. Momentary affect was significantly associated with trait rumination (r = -.33, p < .01). There was also a tendency for momentary affect to be negatively correlated with BDI-II score at baseline (r = -.21, p = .09). Surprisingly, no significant relationship was found between momentary rumination and other trait measures (all r < .15, p > .23; see Table 2 for details).

Table2. *Correlations between BDI-II scores, RRS scores, momentary measurements and entropy (N = 63).*

	1	*2*	*3*	*4*	*5*	*6*	*7*
1. BDI_II T1	-	.51***	.45***	.50***	.06	-.21†	.11
2. BDI_II T2		-	.29*	.50***	.15	-.11	.23†
3. RRS T1			-	.64***	.09	-.33**	.24†
4. RRS T2				-	.13	-.15	.35***
5. Momentary rumination					-	-.31*	.68***
6. Momentary affect						-	-.28*
7. Entropy							-

Note: $^{\dagger}p$< .1; *p< .05; **p< .01; ***p< .001. BDI-II, Beck Depression Inventory-II; RRS, Ruminative Response Scale; T1, baseline measurement; T2, six weeks follow-up.

Structure of the dynamic pattern of momentary rumination and affect

The mean level of entropy was 3.02 (*SD* = 0.41; *range* = 1.70-3.65). Entropy was significantly correlated with momentary rumination (r = .68, p < .001) and momentary affect (r = -.28, p < .05). Furthermore, participants reporting higher levels of trait rumination at baseline, showed a tendency to subsequently demonstrate more entropy during the daily assessments (r = .24, p = .054), whereas baseline depressive symptomatology was not related to entropy (r = .11, p = .40).

Predicting depressive symptoms and trait rumination at six weeks follow-up

We used Hierarchical Regression Analysis (HRA) to examine whether the structure of the dynamic pattern of rumination and affect in daily life (i.e. entropy) can predict depressive symptoms and trait rumination separately, after controlling for the contributions of trait rumination and depressive symptoms at baseline. Due to the violation of the homoscedasticity assumption, we adopted heteroscedasticity-consistent inference (HC-inference; Hayes & Cai, 2007). In addition, given that BDI-II and RRS at time 1 as predictors in HRA are correlated with each other, collinearity issues may arise when using standardized regression coefficients. As a result, we used relative weight analysis (Johnson, 2000; Johnson & LeBreton, 2004; Tonidandel & LeBreton, 2015) to provide additional variance partitioning information, which has been proposed to be more accurate when predictor variables correlate with one another. Therefore, the contribution of each predictor presented below accounted for the

variance of the outcome variable in two different ways: (1) Proportion of contribution obtained from the HRA shows the unique contribution of each predictor above and beyond other predictors, whereas (2) proportion of contribution obtained from relative weight analysis shows the specific contribution of each predictor including its direct effect and its effect in combination with other predictors.

In the HRA predicting depressive symptoms at time 2, we entered BDI-II and RRS at time 1 as predictors in the first step and entropy as predictor in the second step. The results are shown in Table 3. The result of the HC-inference revealed that baseline depressive symptomatology formed a significant predictor for depressive symptoms at time 2 ($p < .001$), accounting for 22% of the variance. However, trait rumination at time 1 did not significantly predict depressive symptoms at time 2 ($p = .83$). In contrast, after controlling for both depressive symptomatology and trait rumination at time 1, entropy formed a marginally significant predictor ($\Delta R^2 = .03$, $p = .07$). These findings suggest that there was a tendency for entropy to explain 3% of depressive symptoms at time 2 beyond and above baseline depressive symptoms and trait rumination. The relative importance weight of entropy confirmed that it can explain 3% of the variance of depressive symptoms at time 2 ($\varepsilon = .03$).

Likewise, for trait rumination at six weeks follow-up, we entered baseline trait rumination and depressive symptomatology as predictors in the first step, and entropy as predictor in the second step. The result (see Table 4) showed that trait rumination at time 1 significantly predicted trait rumination at time 2 ($p < .001$) and accounted for 28% of the variance of trait rumination at time 2. There was a tendency for baseline depressive symptomatology to predict trait rumination at time 2 ($p = .06$). Importantly, entropy explained an additional 4.1% of variance in trait rumination scores at six weeks follow-up ($p < .05$) after controlling for baseline depressive symptomatology and trait rumination. The results of relative importance analysis indicated that the direct and combined effects of entropy in total accounted for 8% of the trait rumination at time 2.

Notably, whereas the above presented findings suggest the predictive potential of the dynamic *structure* of momentary rumination and affect for depressive symptomatology, the *content* on its own (i.e., mean levels of momentary rumination and affect) did not significantly predict depressive symptoms at time 2. That is, when entered together in a regression model to predict depressive symptomatology at time

2, the predictive effects of mean levels of momentary rumination and affect did not reach significance (all *ps* > .21; see Table 3 for details). Momentary rumination could explain 2% of variance of depressive symptoms at time 2 whereas momentary affect could only account for 0.1% of the variance. Similar results were obtained when predicting trait rumination at time 2 (see Table 4 for details): neither momentary rumination nor momentary affect were found to significantly predict trait rumination at six weeks follow-up (all *ps* > .18). Both of them could only account for 1% of the variance of trait rumination at time 2. Hence, the results of the content of the dynamic patterns suggest a specific contribution of structural dynamics in predicting depressive symptoms and trait rumination at time 2.

Table3. *Hierarchical regression analysis predicting BDI-II after six weeks.*

Steps	*Predictors*	*ΔR2*	*B*	*ε*
Structure				
Step 1		.26***		
	BDI-II T1		.47***	.22 [.007; .431]
	RRS T1		.07	.04 [.007; .175]
Step 2		.03†		
	BDI-II T1		.48***	.22 [.069; .422]
	RRS T1		.03	.04 [.008; .156]
	Entropy		.17†	.03 [.002; .119]
Content				
Step 1		.26***		
	BDI-II T1		.47***	.22 [.007; .431]
	RRS T1		.07	.04 [.007; .175]
Step 2		.02		
	BDI-II T1		.48***	.22 [.070; .419]
	RRS T1		.08	.04 [.006; .160]
	Momentary Rumination		.14	.02 [.001; .123]
	Momentary Affect		.06	.001 [.001; .053]

Note: †*p*< .1; **p*< .05; ***p*< .01; ****p*< .001. RRS, Ruminative Response Scale; BDI-II, Beck Depression Inventory-II; T1, baseline measurement; ε, relative importance weight.

Table4. *Hierarchical regression analysis predicting RRS after six weeks.*

Steps	*Predictors*	*ΔR2*	*B*	*ε*
Structure				
Step 1		.46***		
	RRS T1		.52***	.31 [.140; .506]
	BDI-II T1		.26†	.15 [.037; .327]
Step 2		.04*		
	RRS T1		.46**	.28 [.119; .471]
	BDI-II T1		.26†	.14 [.036; .308]
	Entropy		.21*	.08 [.019; .175]
Content				
Step 1		.46***		
	RRS T1		.52***	.31 [.140; .506]
	BDI-II T1		.26†	.15 [.037; .327]
Step 2		.02		
	RRS T1		.54***	.30 [.128; .502]
	BDI-II T1		.27†	.15 [.036; .299]
	Momentary Rumination		.11	.01 [.001; .091]
	Momentary Affect		.12	.01 [.005; .059]

Note: †p< .1; *p< .05; **p< .01; ***p< .001. RRS, Ruminative Response Scale; BDI-II, Beck Depression Inventory-II; T1, baseline measurement; ε, relative importance weight.

DISCUSSION

The present study aimed to investigate the predictive contribution of the dynamic structure (i.e., entropy) of rumination and affect in daily life to depressive symptoms and trait rumination in an unselected sample. We found that entropy marginally significantly predicted depressive symptomatology and significantly predicted changes in trait rumination at six weeks follow-up while taking into account baseline depressive symptoms and trait rumination.

The current results showed a tendency that entropy predicted changes in depressive symptoms at six weeks follow-up. In line with previous study (Koster et al., 2015), these findings suggest that more disorganized patterns of thought and affect predict more symptoms later on. Although there was only a tendency for this predictive effect of entropy on depressive symptoms, it should be noted that the presented predictive effects were attained after controlling for the contribution of both depressive symptoms and trait rumination at baseline. Similarly, we also found that entropy

predicted the changes in trait rumination at six weeks follow-up. The latter finding is consistent with previous study (Koster et al., 2015) showing that entropy marginally significantly predicted depressive rumination[2] in both remitted depressed and healthy control participants after six months.

Interestingly, in our study, we found that only entropy but not the content variables (i.e., mean level of momentary rumination and affect) showed a predictive effect on depressive symptoms after six weeks. In fact, visit entropy in the state space grid can be considered as one of the most content-independent measures of variability (Hollenstein, 2013). These results provide additional support for previous findings that the structure of emotional states contributes distinctively to the prediction of psychopathology (for a review, see Hollenstein et al., 2013). Although the content variables in the current study were not predictive of psychopathology, it is important to notice that the content variables could still provide meaningful information (Kuppens, Oravecz, & Tuerlinckx, 2010; Pasyugina et al., 2015). The findings concerning the predictive value of entropy of our study simply emphasize that the structure itself may have its specific contribution to the prediction of depressive symptoms and trait rumination.

The observation that higher entropy is predictive for higher future levels of depressive symptoms and trait rumination raises questions regarding the potential (mal)adaptive nature of variability within a system. It has been proposed that the concept and the effect of variability should be considered within context. Concerning the relation between variability and mental health, a non-linear relationship has been proposed (Guastello, 2015), which suggests that adaptive systems may display variability in mid-range values. In contrast, too low levels of variability would represent a rigid system whereas too high levels of variability may represent a disordered system, both of which are assumed to be maladaptive (in terms of flexible adaptation to daily

[2] Here, we only provided the results for total trait rumination scores without taking into account the scores in the brooding and reflection subscales. In contrast, in the previous study no total rumination scores were available given that only the brooding and reflection subscales were assessed (Koster et al., 2015). However, it is important to note that in our current study, when we include brooding or reflection as DVs in the HRA analysis, no significant results were obtained. This might be due to the fact that the total rumination score allows more variability than the scores in the subscales.

life stressors). Indeed, in a meta-analysis it has been shown that too much unpredictability (operationalized as higher levels of self-complexity) has a moderate depressogenic effect (Rafaeli-Mor & Steinberg, 2002).

Our findings have potential implications for understanding the development and prevention of depression. First, previous research indicates that the impact of rumination on negative affect does not predict change in depressive symptoms (Pasyugina et al., 2015). However, DST proposes that the whole system presents specific characteristics that cannot be observed within sub-components. In the current study the predictive effect of entropy on trait rumination and depressive symptoms suggests that the dynamic pattern of momentary rumination and affect can contribute to the development of depression. Second, according to the DST, increased variability may represent an early warning signal of system transition (Hayes et al., 2015). The fact that higher levels of entropy were associated with higher levels of trait rumination may indicate that the systems of those who are vulnerable to depression are more unstable and have potentials to change. It may imply a critical period for carrying out interventions that may prevent these dynamic patterns from changing into more rigid depressive patterns (Tschacher, Scheier, & Grawe, 1995).

There are some limitations to our study. First, the follow-up measurements were conducted after six weeks which is still relatively short for monitoring change in depressive symptomatology, especially if one wants to explore the predictive value of entropy for occurrence of depressive episodes (e.g., entropy as an affective risk marker). Assessing depressive symptoms over a longer period may provide additional information about the prospective influence of the dynamic pattern. Second, there are a wealth of constructs that assess different aspects of the dynamic pattern. Future studies should consider other dynamic attributes as well in order to gain a more comprehensive view of the dynamic pattern between rumination and affect and its predictive effect on depressive symptoms. Third, momentary rumination was not significantly correlated with trait rumination in our study, whereas some studies that explored the association between momentary rumination and trait rumination have shown medium positive correlations between both constructs (Moberly & Watkins, 2008; Pasyugina et al., 2015). This result might be due to the specific setting in the current study in which the order of the momentary measurements was randomized not

only within the two items of rumination itself, but also between assessments of rumination and affect. As such, the measure of rumination was not always followed by the measure of affect which may bias the evaluation of rumination based on the value of affect. Similar findings were reported by Huffziger et al. (2013), where momentary rumination was *not* significantly associated with brooding at baseline in the remitted depressed group and with reflection at baseline in the healthy control group.

CONCLUSION

Our experience sampling study investigated whether the structure of the dynamic pattern of (i.e., entropy) rumination and affect in daily life predicts future depressive symptoms and trait rumination. We found that there was a tendency for entropy to predict depressive symptoms at six weeks follow-up after controlling for baseline depressive symptomatology and trait rumination. Entropy also was a significant predictor for trait rumination at six weeks follow-up. Overall, our findings provide evidence that the structure of the dynamic pattern of momentary rumination and affect has its specific contribution to the development of depression and trait rumination.

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CHAPTER 7

GENERAL DISCUSSION

Remember the time when we broke up with someone or when our beloved pet died? We were overwhelmed with sadness. We may think again and again about those difficult moments as well as how bad our feelings were. After a while, some people may be able to stop such negative thinking, but for others, it seems very difficult to get rid of those sad thoughts. This raises the question of what factors make some people tend to ruminate more often than others, and how people who ruminate get trapped in the vicious cycle of rumination. To address these issues, several theoretical frameworks have been proposed, such as the cognitive inhibition hypothesis (Joormann, 2010), and the account of the impaired disengagement hypothesis (Koster, De Lissnyder, Derakhshan, & De Raedt, 2011), both of which characterize individuals in high trait rumination as having impaired cognitive control for negative information. Consistent with these theoretical frameworks, a large number of studies have shown that high levels of rumination are associated with impaired cognitive control (i.e., inhibition or attentional disengagement) for negative stimuli. However, cognitive control difficulties have also been found in some previous studies where non-negative stimuli were presented (Joormann, 2006; Joormann & Tran, 2009; LeMoult, Arditte, D'Avanzato, & Joormann, 2013). A recent cognitive model- the attentional scope model of rumination- has been developed, trying to provide explanations for these mixed findings in a more complex view of the cognitive control mechanisms of rumination (Whitmer & Gotlib, 2013).

With regard to the first issue, the attentional scope model of rumination states that individual differences in the attentional scope are important cognitive factors that make some individuals ruminate more than others (Whitmer & Gotlib, 2013). They argued that when individuals with a narrow attentional scope are in a negative mood,

the negative-mood congruence bias would make their restrained attention scope only focus on negative information. In contrast, when they are in a neutral mood, there is no negative attentional bias. Consequently, the constrained way of allocating attentional resources can affect their processing of both negative and other valences of information. With these hypotheses, this model can potentially interpret previous contradicting findings that rumination is associated with processing difficulties not only in negative stimuli but also in positive or neutral stimuli. However, until now, few empirical studies have directly tested the assumptions of this model (e.g., Grol, Hertel, Koster, & De Raedt, 2015). Therefore, the aim of the first research line of this doctoral project (Chapter 2, 3 and 4) was to explore the relation between attentional scope and rumination based on the hypotheses made by the attentional scope model of rumination. Specifically, we focused on whether the association of attentional scope and rumination could be found when processing all types of information, and whether changing attentional scope could causally affect rumination.

Noteworthy, even if people ruminate, it may not always be followed with negative consequences. Some researchers have argued that ruminative thinking is not necessarily a maladaptive emotion regulation strategy, but it is the persistent or habitual use of rumination that is associated with impaired problem solving, increasing negative emotions and development of depression (Koster et al., 2011; Watkins & Nolen-Hoeksema, 2014). Indeed, rumination has also proved to have adaptive effects under certain conditions (Watkins, 2004; 2008). To investigate how individuals who ruminate develop maladaptive rumination, it is important to examine how ruminative thinking changes in daily life. According to the attentional scope model of rumination, individuals who tend to ruminate quite often have a more narrow attentional scope so that they devote more attentional resources into what they are currently attending, which induces deeper encoding of the information which is in the centre of their attention (Whitmer & Gotlib, 2013). This may lead to a better performance (and probably a positive mood) when in the situation that requires focused attention, whereas in a situation that asks for distributing attentional resources in a more extended way, processing information with a narrow attentional scope may result in a relatively poor performance (and perhaps a negative mood). Thus, the daily dynamics of ruminative thinking and affect in high ruminators, who in general ruminate more across

contexts, are supposed to be more complex than in low ruminators. This putatively unstable dynamic pattern may be associated with maladaptive trait rumination and future depressive symptoms. The second research line aimed to address this issue with experience sampling studies (Chapter 5 and 6), exploring the daily dynamics of momentary ruminative thinking and affect. The association between daily dynamics and maladaptive dispositions was then investigated by examining the predictive effect of the daily dynamics of ruminative thinking and affect on the follow-up measurements of trait rumination and depressive symptoms.

The main findings and contributions of this doctoral project are summarized below.

THE RELATION BETWEEN ATTENTIONAL SCOPE AND RUMINATION

To systematically investigate the propositions of the attentional scope model of rumination, a series of studies have been conducted. In **Chapter 2**, we tested the prediction that individuals with high levels of rumination may have a more narrow scope of attention. This would affect their processing of not only negative information but also neutral information when they are not in a negative mood (Whitmer & Gotlib, 2013). High and low ruminators were recruited after pre-screening based on their RRS scores. A well-validated moving window paradigm was employed to measure attentional scope, during which participants' eye movements were recorded (McConkie & Rayner, 1975). Participants were asked to read the sentences as usual and try to understand their meaning. In the small, medium and large window size conditions, participants could only see the characters within an invisible window, which moves with individuals' gaze fixation, whereas the text outside the window was covered with blank. They also performed in a no-window condition as a natural reading reference, where all characters of the sentence were presented on the screen. The rationale of this paradigm is that when the window size is narrower than individuals' attentional scope, then they would process the sentence with more difficulties than when they read in a natural condition. Correspondingly, when the window size is as large as, or larger than, individuals' attentional scope, they would read the sentence as if they were in the

natural reading condition. The positive and negative mood on baseline were assessed to control for mood influence on attentional scope, and neutral self- and other-related sentences were used as reading material. The results of this study revealed that individuals in the high trait rumination group read faster, reflecting by shorter total time of reading, larger reading rate, and using less number of fixations than individuals in the low trait rumination group across self- and other-related sentences in the small window size condition, which was the most difficult reading condition relative to the natural reading condition (no-window condition). Therefore, these results suggested that high ruminators exhibit a more narrow attentional scope when processing neutral information. These findings are compatible with the hypothesis of the attentional scope model of rumination that narrow attentional scope can affect the information processing of neutral information when high ruminators are in neutral mood.

However, because only neutral sentences were selected as the reading material in this study, we cannot generalize these findings into other types of valence. Hence, a second study was conducted (**Chapter 3**) to examine whether the relation between attentional scope and rumination could be observed in relation to different valences of information. For this purpose, negative, neutral and positive sentences were included as reading material in the same moving window paradigm. Different division of areas of interest were also made to provide precise details with regard to the processing of emotional and non-emotional words of each sentence. The results of a sample with sufficient variation in trait rumination demonstrated that individuals with high levels of rumination exhibit a narrower attentional scope than individuals with low levels of rumination when reading all the presented valences of sentence after controlling for baseline mood. Taken together, our findings of Chapter 2 and 3 provided evidence for the main predictions of the attentional scope model of rumination concerning the relation between attentional scope and rumination, that when individuals are not in a negative mood, high ruminators show a constrained attentional scope when processing both neutral and emotional information. Interestingly, in the second study (Chapter 3), the faster total reading time of high ruminators was no longer observed when processing negative information in the small window size condition. This may indicate that, even though attention is more focused in general, across all valences of

information, high ruminators may still treat negative information differently from non-negative information.

In the first two studies, we reported an observed association between attentional scope and rumination, but due to the cross-sectional nature of the design, the causal direction of this link is still not clear. Therefore, we ran a training study in which attentional scope was manipulated, in order to investigate the causal effects of attentional scope on rumination (**Chapter 4**). Previous studies have shown that training attentional scope with only one task in a single-session did not work successfully in modulating attentional scope (Fang et al., in press). To strengthen training effect, we adopted a multiple-session training (5 days) with a combination of a modified version of Global-Local task (Navon, 1977) and a visuospatial training task (Fang et al., in press). The transfer effects of training on attentional scope were assessed with a Global-Local assessment task and with a visuospatial attentional breadth assessment task (Bosmans, Braet, Koster, & De Raedt, 2009; Grol et al., 2015). Moreover, the transfer effects of training on rumination were tested when participants were confronted with a realistic stressful situation under lab conditions. Surprisingly, only a narrowing effect was observed in the Global-Local assessment task, whereas there was no other evidence that training yielded the intended effect neither on the Global-Local assessment task nor on the visuospatial attentional breadth assessment task. As a result, we cannot make any firm conclusions about the causal link between attentional breadth and rumination.

PREDICTIVE EFFECT OF DYNAMICS OF RUMINATIVE THINKING AND AFFECT ON TRAIT RUMINATION AND DEPRESSION

The studies presented in previous chapters (Chapter 2, 3, and 4) sought to address the question concerning what cognitive factors make some individuals ruminate more often than others by exploring the relation between attentional scope and rumination. However, how daily ruminative thinking is associated with maladaptive trait rumination and future depressive symptoms is still unclear. To uncover the dynamics of daily ruminative thinking and mood, we conducted a secondary analysis

(**Chapter 5**) on an experience sampling study, in which remitted depressed patients and never-depressed individuals were asked to evaluate their momentary rumination and mood ten times a day during two consecutive days (Huffziger et al., 2013). We put these two momentary measurements into a Dynamic System theory (DST) framework, which states that a dynamic system is a system with different components that change over time (Lewis & Granic, 2000; Thelen & Smith, 1998). In terms of the DST, the changing momentary rumination and mood can be considered as two components of a dynamic system. We used entropy, a measure of the amount of information generated as a system changes (Mitchell, 2009; Shannon & Weaver, 1949; Young, 2003), as the main index in depicting the dynamics of the whole system. Additionally, their depressive symptoms and trait rumination were assessed at baseline and at six months follow-up. We found that entropy predicted depressive symptoms at six months follow-up only in remitted depressive patients. More precisely, a higher level of entropy, which represents a highly disorganized dynamic pattern of ruminative thinking and mood, was associated with more depressive symptoms at follow-up in remitted depressive patients. In addition, there was a tendency that entropy predicted the brooding subtype of rumination at follow-up in both groups.

Intriguingly, since the mean levels of entropy were not significantly different between two groups, it is possible to speculate that the functional organizations of the two systems are intrinsically different. While more variable fluctuations in remitted depressed individuals represent a marker of future depressive symptoms, the same level of variability does not signal any future maladjustment in healthy individuals. In line with this interpretation, it has been suggested different populations (and different systems) could have different optimal levels of entropy (Cunningham, Dunfield, Stillman, 2013). This, in turn, potentially implies the existence of group-specific thresholds in marking the transition between constructive and unconstructive variability (flexibility *vs*. instability; Hollenstein, Lichtwarck-Aschoff, & Potworowski, 2013).

It should be noted that the healthy controls in previous study (Chapter 5) were selected strictly as a comparative group (i.e., never depressed individuals) to remitted depressive group so that they had relatively low levels of depressive symptoms at baseline. It remains unknown whether and how the dynamics of ruminative thinking

and mood in daily life predicts future trait rumination and depressive symptoms in a more general population. Therefore, a more intensive experience sampling study was conducted (**Chapter 6**), in which participants in an unselected sample with sufficient variation in depressive symptoms and trait rumination were asked to rate their momentary ruminative thinking and affect eight times a day within seven days. Their trait rumination and depressive symptoms were measured at baseline and at six weeks follow-up. Entropy was found to significantly predict trait rumination and to marginally significantly predict depressive symptoms at follow-up after controlling for the baseline depressive symptoms and trait rumination. In accordance with our previous study (Chapter 5), higher levels of entropy were associated with higher levels of trait rumination and depressive symptoms after six weeks. Crucially, entropy could explain more variance of future depressive symptoms and trait rumination than mean level of momentary measurements. These findings are in line with previous studies revealing that the structure of a dynamic system (e.g., entropy) has its specific contribution to the prediction of psychopathology (Hollenstein et al., 2013).

IMPLICATIONS FOR THEORY, RESEARCH AND PRACTICE

Attentional scope model of rumination

Our findings are in accordance with the hypothesis from the attentional scope model stating that high ruminators exhibit a more narrow attentional scope when processing different types of information, when they are not in a negative mood (Whitmer & Gotlib, 2013). These findings are also consistent with previous studies that showed different performances between high and low trait ruminators in the processing of not only negative but also non-negative materials (Joormann, 2006; Joormann & Tran, 2009; LeMoult et al., 2013). The attentional scope model of rumination points out that when individuals are in a neutral mood, there are no emotion-related attentional biases modulating the processing of specific type of information so that the narrow attentional scope can be used in processing of all information independent of their valence. Of note, though participants in the studies

reported did not provide information about their current mood state, participants showing rumination-related poor performance on both negative and non-negative stimuli, were all non-depressed individuals. Thus, they in general show less persistent negative mood than clinical depressive patients, and may then be less influenced by negative-emotion congruent attentional bias (e.g., Joormann & Tran, 2009). In both of our eye movement studies, the narrowing effect on performance still exist after controlling for baseline mood states. Our findings provide more direct evidence that the association between attentional scope and rumination is not driven by mood. In contrast, the valence-specific impairment related to rumination was mainly observed in dysphoric (Joormann, 2004) and clinically depressed patients (Goeleven, De Raedt, Baert, & Koster, 2006). Noteworthy, there were studies using non-depressed samples that showed valence-specific impairment with high ruminators (Southworth, Grafton, MacLeod, & Watkins, 2017). Nevertheless, some of them can still be interpreted by the attentional scope model of rumination. For example, Vålenas and colleagues (2017) reported that rumination was associated with impaired disengagement of attention from negative words in undergraduates who were preparing mid-term exams. In light of the assumptions of the attentional scope model of rumination, this stressful period might cause a negative attentional bias that had already constrained the narrow attentional scope in negative-related stimuli.

Moreover, even though high ruminators have been proposed to exhibit narrower attentional scope in the processing all types of stimuli, there is still the possibility that they attended differently to different information with specific self-references and/or valences. Our research also took the feature of information's self-reference and valence into account. Since rumination is characterized as self-related repetitive thoughts (Rimes & Watkins, 2005; Takano, Sakamoto, & Tanno, 2013; Watkins, 2004; Whitmer & Gotlib, 2012) and has been related to increased activation of the neural network involved in self-referential processing (Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Ray et al., 2005), self- and other-related sentences were used in the first eye movement study (Chapter 2). The findings showed that high levels of trait rumination were associated with a narrow attentional scope across self- and other-related sentences. This adds to the assumptions of the attentional scope model of rumination with regard to the types of information it encompassed, which mainly

refer to the valence of information. Contrary to our findings, Grol et al. (2015) reported that individuals with higher levels of trait rumination who underwent a state rumination induction showed a more narrow attentional scope for self-related information relative to other-related information. The incompatible findings may be in part due to the fact that self-involvement has been activated in the rumination induction, in which self-related scenario were provided to all participants (Grol et al., 2015), while in our study there was no explicit instruction facilitating self-involvement.

In order to test possible differences in the processing of different valences, in our second eye movement study (Chapter 3), we included neutral, positive and negative sentences which were all self-related. The results in the differential total reading time between negative sentences and non-negative sentences indicated that even though high ruminators have a narrow attentional scope when processing all types of information in neutral mood, they may still show different responses toward negative information. Previous studies have shown that high levels of trait rumination are associated with attentional bias towards negative information relative to positive or/and neutral stimuli (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Donaldson, Lam, & Mathews, 2007). The attentional scope model of rumination argues that when individuals are in negative mood, negative attentional bias makes them only focus on negative self-related events. Alternatively, when there is lack of negative attentional bias, a narrow attention scope should be found also when dealing with non-negative information. Our findings support the latter prediction but also suggest that high ruminators may use more time to process negative information. However, the underlying mechanism of these observations is not clear yet and further research is warranted to clarify this question.

The laboratory experiments in this project have suggested an association between attentional scope and trait rumination. However, it is still unclear how this narrowing effect can be demonstrated in a more ecological assessment, and whether it can be used to explain how people who ruminate more often develop the maladaptive habit of rumination in daily life. For this purpose, we explored the dynamic patterns of ruminative thinking and affect in two experience sampling studies in remitted depressed sample (Chapter 5) and a more general unselected sample (Chapter 6). In light of the attentional scope model of rumination, the narrow attentional scope of high

ruminators can be observed when processing different types of information. This may imply that they ruminate not just under negative situation but also under other circumstances (e.g., in non-negative conditions). For example, ruminative thinking about positive mood and information has been reported in a high positive mood state (Feldman, Joormann, & Johnson, 2008; Raes, Smets, Nelis, & Schoofs, 2012). In addition, the consequences of ruminative thinking are not always maladaptive. As such, the dynamics patterns of ruminative thinking and affect in daily life are supposed to be more complexed for high trait ruminators when they are not in a depressive episode. Indeed, both of our two ESM studies revealed a tendency that higher levels of rumination were associated with higher levels of entropy.

Furthermore, considering how daily ruminative thinking develops to maladaptive trait rumination as well as increases depressive symptoms, our findings showed that higher levels of entropy were associated with higher levels of trait rumination and depressive symptoms at the follow-up assessments. Previous research has suggested that emotion regulation strategy that is not suitable for the current situation has detrimental impact on well-being (Haines et al., 2016; Troy, Shallcross, & Mauss, 2013). Accordingly, our findings that higher levels of entropy predicted higher future depressive symptoms may in part be due to the fact that individuals with higher levels of entropy ruminate without considering whether it fits the demands of the context. However, we cannot make sure whether this is the case, because we did not measure the details of the context connected with each measurement of ruminative thinking in our ESM studies. Additionally, although our findings that higher levels of entropy predicted higher future trait rumination can possibly be explained by the attentional scope model of rumination, since we did not assess individuals' attentional scope before daily measurement, the proposed link between attentional scope and entropy still needs more direct evidence. Taken together, the findings in the experience sampling studies of this dissertation provide insight into extending the hypotheses of the attentional scope model of rumination into daily life experience. Future studies should try to specify the precise patterns involved in the daily dynamics of ruminative thinking and affect by including the attentional information of individuals and daily context.

Attentional scope training

If individuals get stuck in the vicious cycle of rumination, is it possible for psychotherapeutic interventions to specifically tackle the problem of their ruminative thinking? Previous research has shown that cognitive-behaviour therapy that directly target rumination has promising treatment effects in ameliorating maladaptive ruminative thinking, and further enhancing the treatment in depression (Watkins, 2009; 2016; Watkins et al., 2007). Our research also contributes a new perspective to the repertoire of training that specific focus on rumination. The findings of the lab studies and real life experience sampling studies in this dissertation suggest that not only the content of self-focused thought but also thinking in a restrained manner is associated with depressive rumination and depressive symptoms. However, it should be emphasized that a narrow attentional scope can be either detrimental by making individuals vulnerable to rumination or beneficial by helping people focus on the task at hand and avoiding distractive interference (Whitmer & Gotlib, 2013). Specifically, on the one hand, trait ruminators performed better than low ruminators on tasks that need people to maintain their attentional focus in task-relevant information (Altamirano, Miyake, & Whitmer, 2010; Zetsche & Joormann, 2011), whereas broad attentional scope decreased the quality of encoded information (Vanlessen, Rossi, De Raedt, & Pourtois, 2013). On the other hand, broad attentional breadth has been related to positive mood (Derryberry & Tucker, 1994; Rowe, Hirsh & Anderson, 2007), improved self-regulation (Hanif et al., 2012), enhanced resilience to stress (Fredrickson, 2004), and increased cognitive flexibility (Olivers & Nieuwenhuis, 2005; Zmigrod, Zmigrod, & Hommel, 2015). In contrast, narrowed attentional breadth has been related to negative emotions (Fenske & Eastwood, 2003; Gable & Harmon-Jones, 2008), attention capture by negative stimuli (Gable & Harmon-Jones, 2012), increased anxiety (Derryberry & Tucker, 1994), and high levels of rumination (Grol et al., 2015). Further, what we have uncovered in this dissertation is that high trait ruminators tend to allocate attentional resources in a constrained way even when they are not in a negative mood. Evidence from a growing number of studies has shown that high levels of rumination are associated with impaired set-shifting (Yang, Cao, Shields, Teng, & Liu, 2016). Combined, it indicates that high ruminators are unlikely to change ruminative

thinking based on certain contexts since their attention is overly focused on their problems. This feature may be related to context-insensitivity which is observed in individuals with high depression scores (Haines et al., 2016). Accordingly, attentional scope training should switch from the goal of trying to change a narrow attentional scope into a broad one to the goal of enhancing the ability of using different attentional allocation strategies in accordance with contextual requirements.

Prevention and treatment of maladaptive rumination and depression

The findings of the two ESM studies showed that higher levels of entropy predicted higher levels of future depressive symptoms and trait rumination. It may seem counter-intuitive, since high variability is readily to be connected with positive qualities, such as flexible to change and creativity. However, it has been argued that whether the implication of high or low variability is adaptive or maladaptive depends on specific situation (Hollenstein et al., 2013). In fact, the concept and the effect of variability should be considered within a specific context. Recently, a non-linear relationship has been proposed regarding the relation between variability and mental health (Guastello, 2015; Lichtwarck-Aschoff, Kunnen, & van Geert, 2009; Lunkenheimer, Olsons, Hollenstein, Sameroff, & Winter, 2011). It states that adaptive systems may display variability in mid-range values. In contrast, too low levels of variability would represent a rigid system, whereas too high levels of variability may represent a disordered system, both of which are assumed to be maladaptive (in terms of flexible adaptation to daily life stressors). Indeed, in a meta-analysis, it has been shown that too much unpredictability (operationalized as higher levels of self-complexity) has a moderate depressogenic effect (Rafaeli-Mor & Steinberg, 2002). According to the dynamic system theory, a system with high levels of entropy tends to change into a more stable system, which then leads to relatively lower levels of entropy. As a result, a system with high levels of entropy is assumed to be vulnerable to disturbance (Carver & Scheier, 1998). On the one hand, if the disturbance is related to stress and negative mood, then increased variability may represent an early warning signal of system transition to a stable depression system (Hayes, Yasinski, Barnes, & Bockting, 2015). On the other hand, if the disturbance is a psychotherapeutic intervention, then the

unstable system may imply a critical period for carrying out interventions that could prevent these dynamic patterns from changing into more rigid depressive patterns (Tschacher, Scheier, & Grawe, 1995). Our findings that higher levels of entropy were associated with higher levels of trait rumination may indicate that the systems of those who are vulnerable to depression are more unstable and have a higher potential to change.

LIMITATION AND FUTURE RESEARCH DIRECTIONS

There are several limitations of this PhD research that require consideration. First, most of the samples we used in this dissertation were unselected general population, except in Chapter 2 where we pre-selected high and low trait ruminators, and in Chapter 5 where the sample contained remitted depressive patients. Therefore, findings of these studies may not be generalized to depressive patients. For instance, individuals that are experiencing a current depressive episode are characterized by suffering prolonged and increased negative affect. The sustained negative-emotion congruent bias would then make them only focus about their negative feeling and its consequences. The findings that high levels of rumination were associated with valence-specific impairment in clinical depressed or dysphorics may support this assumption (Chen, Feng, Wang, Su, & Zhang, 2016; Goeleven et al., 2006). Besides, attentional breadth training may have better effects in individuals with high levels of depressive rumination, considering that healthy, non-clinical participants in general may present good cognitive functioning which causes little space for them to improve. Concerning the daily dynamics of ruminative thinking and affect for depressive trait ruminators, their dynamic patterns may be more rigid, possibly containing a strong attractor state characterized by high levels of momentary rumination and high levels of negative affect. One interesting direction for future studies would be to explore the relation between attentional scope and rumination, and dynamics of momentary ruminative thinking and affect in depressive ruminators.

Second, in this dissertation, attentional scope was always measured at the perceptual level. In Chapter 2 and 3, a moving window task was used to assess the

attentional scope during reading. In Chapter 4, the transfer effects of training on attentional scope were assessed with the Global-Local assessment task (Navon, 1977), and the visuospatial attentional breadth assessment task (Bosmans et al., 2009; Grol et al., 2015). Given that control of internal mental representations is associated with rumination (De Lissnyder et al., 2012), ruminative thinking can be considered as mainly involving internal attention. In contrast, perceptual attention is identified as external attention (Chun, Golomb, & Turk-Browne, 2011). Particularly, visuospatial attention exerts its influence in modulating information that refers to representation of localization (Knudsen, 2007). Therefore, one might speculate that measures of attentional scope at the perceptual level cannot fully uncover the attentional distribution involved in rumination. Likewise, training attentional scope at perceptual level may limit the effectiveness of training on rumination.

However, we would argue that there are a number of similarities between external attention and internal attention (Chun et al., 2011). For example, it is well-established that both of them have restricted capacities. Consequently, individuals have to decide how to distribute their limited attentional resources when performing both external and internal attention tasks. Moreover, a region at superior parietal cortex has been found to be a common region that involved in switching spatial attention, task set and memory representations (Esterman, Chiu, Tamber-Rosenau, & Yantis, 2009). In addition, it has been shown that working memory contents can reciprocally interact with perceptual attention (Dell'Acqua, Sessa, Jolicoeur, & Robitaille, 2006; Lepsien, Griffin, Devlin, & Nobre, 2005). These findings may imply that assessing and training attentional scope at the perceptual level can still provide meaningful insights into the attentional allocation related to rumination. Still, future studies should use attentional scope manipulation and assessment that specifically target internal attention allocation and that operate at perceptual level.

Third, in Chapter 4 we intended to manipulate attentional scope in an intensive multiple-session training to examine its effect on rumination, but we failed to find evidence that attentional scope has been modulated as expected. Thus, the causal relationship between rumination and attentional scope is still unknown. Nevertheless, previous studies have indirectly indicated that rumination can be reduced through expanding attentional scope. For example, physical exercise, which was reported to

induce a tendency related with broadened attentional scope (Barnes, Coombes, Armstrong, Higgins, & Janelle, 2010) has been reported to be associated with decreased ruminative thinking at three and nine weeks follow-up (Craft, 2005). Future studies should continue to investigate whether manipulating attentional scope has a causal impact on rumination.

One thing may be worth considering when selecting a better way to manipulate attentional scope. Though accumulated evidence has suggested that positive mood can expand attentional scope (Hüttermann & Memmert, 2015; Rowe et al., 2007; Vanlessen et al., 2016), it is inappropriate to enlarge attentional scope by inducing positive mood. Because positive mood is strongly related to rumination and also positive mood may elicit other factors rather than pure attentional scope, such as impaired inhibitory control (Rowe et al., 2007). These may compound the need for detecting the effect of attentional scope which mainly refers to attentional resources allocation to task relevant stimuli and inhibition of unattended distractive information. Besides, the effect of positive mood has been shown to disappear fast (Vanlessen et al., 2013). More stringent manipulation is needed in order to provide validated and stable change of attentional scope.

The limitation of our ESM studies is that we only carried out daily momentary measurement once without implementing any manipulation or induction (e.g., stressful induction). Thus, we cannot provide information about how people at risk of depression, such as high ruminators, develop a depressive episode after being confronted with stressful events. In terms of the Dynamic Systems Theory, the transition from a highly disorganized dynamic pattern to a rigid stable depressive system remains unknown. Also, not much has been investigated about how psychotherapy turns a rigid depressive system into a more flexible well-functioned system. Future research could consider using naturalistic stressful situations as external detrimental influences or, alternatively, using cognitive training as external beneficial influence. By comparing dynamic patterns of ruminative thinking and affect before and after these interventions, we can explore the transition at a system level, and also the resilient ability of a system that reflects its speed of recovery after perturbation.

GENERAL CONCLUSION

Attentional scope is one of the most important cognitive factors that are associated with the repetitive nature of rumination. The attentional scope model of rumination sought to explain the primary source of individual differences that makes some individuals ruminate more than others when encountering sad situations. This doctoral project set out to test different proposals of this model and our work has provided supportive evidence for its main predictions. We have demonstrated that individuals high in trait rumination exhibit a more narrow attentional scope in the processing of both neutral and emotional information when they are not in a negative mood. Moreover, our findings extended the application of this model to daily life context. The unstable and depressogenic dynamic patterns of ruminative thinking and affect in high trait ruminators reported in our experience sampling studies may reflect their usage of a constrained thinking style in inappropriate situations. However, due to the limited success of attentional breadth manipulations in our multiple-session training, we cannot draw any conclusion regarding the causal direction between attentional scope and rumination. Also, it remains unclear how exactly the daily dynamics of high ruminators transform after perturbation either caused by stressful events or by psychotherapy. Future studies are needed to investigate the potential effect of attentional scope on rumination, providing evidence not only from stringent laboratory experiments but also from a more ecological assessment of momentary rumination and affect in the ever-changing environments. This may help us gain a more comprehensive understanding of how attentional scope interacts with rumination, and as such provide insights into the development of a better treatment and prevention plan for individuals high in trait rumination, who are related to increased risk for depression.

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Zmigrod, S., Zmigrod, L., & Hommel, B. (2015). Zooming into creativity: individual differences in attentional global-local biases are linked to creative thinking. *Frontiers in Psychology, 6*, 1-8.

DATA STORAGE FACT SHEETS

% Testing the attentional scope model of rumination: an eye-tracking study using the moving window paradigm

% Author: Lin Fang

% Date: 28/10/2016

1. Contact

==========

1a. Main researcher

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1b. Responsible ZAP

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- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Ernst.Koster@UGent.be

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2. Information about the datasets to which this sheet applies

==========

* Reference of the publication in which the datasets are reported:

Fang, L., Sanchez, A., & Koster, E.H.W. (2016). Testing the attentional scope model of rumination: An eye-tracking study using the moving window paradigm. *Biological Psychology, 123,* 278-285. http://dx.doi.org/10.1016/j.biopsycho.2016.10.011

* Which datasets in that publication does this sheet apply to: All datasets reported in the article.

3. Information about the provided files

==========

3a. Raw data

---

* Have the raw data been stored by the main researcher?

[X] YES / [ ] NO

If NO, please justify: /

*On which platform are the raw data stored?

1. Raw data of questionnaires:

- [X] researcher PC: questionnaires were assessed on paper, typed into an Excel-sheets [Q_mwp_oct14.xlsx]
- [ ] research group file server
- [X] other (specifiy): informed consent files on paper

2. Raw data of moving window tasks:

- [X] researcher PC: moving window task performance [eyemovement_O64.sav]
- [ ] research group file server
- [X] other (specify): back-ups on external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

For 1 and 2:

- [X] main researcher
- [X] responsible ZAP
- [ ] other (specify): ...

3b. Other files

---

* Which other files have been stored?

- [X] files describing the step-by-step transition from raw data to reported results.

Specify: [data_step_mwp_oct14.txt]

- [X] file(s) containing cleaned data?

Specify: A file containing the cleaned data has been provided for the moving window task [emdata_final61_oct14.sav]

- [X] file(s) containing the scripts of the analyses?

Specify: Script which allows reproduction of the main findings (linear mixed effect models) [Syn_LME_mwp_oct14.sps]

- [X] file(s) providing additional information regarding cleaning of raw data of moving window tasks

Specify: Additional information regarding how raw eye movements data was cleaned /filtered

[emdata_O63.sav][emdata_O61.sav][emdata_filter_fixation.sav][emdata_filter_3sd.sav]

* On which platform are these other files stored?

- [X] researcher PC
- [ ] research group file server
- [X] other (specify): backup external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

4. Reproduction

==========

*Have the results been reproduced?:

[ ] YES / [X] NO

If YES, by whom (add if multiple): /

% Relation between attentional scope and rumination: examination of valence-specificity using a gaze-contingent moving window paradigm

% Author: Lin Fang

% Date: 27/02/2016

1. Contact

==========

1a. Main researcher

- name: Lin Fang
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2. Information about the datasets to which this sheet applies

==========

* Reference of the publication in which the datasets are reported:

Fang, L. (2017). Relation between attentional scope and rumination: examination of valence-specificity using a gaze-contingent moving window paradigm. Chapter 3 in PhD dissertation.

* Which datasets in that publication does this sheet apply to: All datasets reported in the chapter.

3. Information about the provided files

==========

3a. Raw data

---

* Have the raw data been stored by the main researcher?

[X] YES / [ ] NO

If NO, please justify: /

*On which platform are the raw data stored?

1. Raw data of questionnaires:

- [X] researcher PC: questionnaires were assessed on paper, typed into an Excel-sheets [Q_emomwp.xlsx]
- [ ] research group file server
- [X] other (specifiy): informed consent files on paper

2. Raw data of moving window tasks:

- [X] researcher PC: emotional moving window task performance [emdata_O_emomwp.sav]
- [ ] research group file server
- [X] other (specify): back-ups on external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

For 1 and 2:

- [X] main researcher
- [X] responsible ZAP
- [ ] other (specify): ...

3b. Other files

---

* Which other files have been stored?

- [X] files describing the step-by-step transition from raw data to reported results.

Specify: [data_step_emomwp.txt]

- [X] file(s) containing cleaned data?

Specify: A file containing the cleaned data has been provided for the emotional moving window task [emdata_final_emomwp.sav]

* On which platform are these other files stored?

- [X] researcher PC
- [ ] research group file server
- [X] other (specify): backup external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

4. Reproduction

==========

*Have the results been reproduced?:

[ ] YES / [X] NO

If YES, by whom (add if multiple): /

% Can multiple-session attentional breadth training change attentional breadth and rumination?

% Author: Lin Fang

% Date: 22/02/2017

1. Contact

==========

1a. Main researcher

- name: Lin Fang

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Lin.Fang@UGent.be

1b. Responsible ZAP

- name: Prof. dr. Ernst H. W. Koster
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- e-mail: Ernst.Koster@UGent.be

If a response is not received when using the above contact details, please send an e-mail to data-ppw@UGent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium

2. Information about the datasets to which this sheet applies

==========

* Reference of the publication in which the datasets are reported:
Fang, L., Hoorelbeke, K., Bruyneel, L., Notebaert, L., MacLeod, C., De Raedt, R., & Koster, E.H.W. (2017). Can training change attentional breadth? Failure to find transfer effects. *Psychological Research*. DOI 10.1007/s00426-017-0845-y.
* Which datasets in that publication does this sheet apply to: All datasets reported in the article.

3. Information about the provided files

==========

3a. Raw data

---

* Have the raw data been stored by the main researcher?
[X] YES / [ ] NO
If NO, please justify: /

*On which platform are the raw data stored?
1. Raw data of questionnaires:

- [X] researcher PC: questionnaires were assessed on paper, typed into an Excel-sheets [Q_ABTraining_Exp3.xlsx]
- [ ] research group file server
- [X] other (specifiy): informed consent files on paper

2. Raw data of computer tasks:
- [X] researcher PC: Global-Local task performance [Exp3prefull.xlsx], [Exp3postfull.xlsx]; Attentional breadth assessment task performance [Exp3_AB_ASS_PRE.xlsx],[Exp3_AB_ASS_POST.xlsx]
- [ ] research group file server
- [X] other (specify): back-ups on external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?
For 1 and 2:
- [X] main researcher
- [X] responsible ZAP
- [ ] other (specify): ...

3b. Other files
---
* Which other files have been stored?
- [X] files describing the step-by-step transition from raw data to reported results.
Specify: [data_step_as_training.txt]
- [X] file(s) containing cleaned data?
Specify: The cleaned data have been provided for attentional breadth assessment: [exp3ss56_20161216.sav]

* On which platform are these other files stored?
- [X] researcher PC
- [ ] research group file server
- [X] other (specify): backup external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

4. Reproduction

==========

*Have the results been reproduced?:

[ ] YES / [X] NO

If YES, by whom (add if multiple): /

% Examining the relation between mood and rumination in remitted depressed individuals: a dynamic systems analysis

% Author: Lin Fang

% Date: 26/03/2017

1. Contact

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1a. Main researcher

- name: Lin Fang
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- name: Prof. dr. Ernst H. W. Koster
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2. Information about the datasets to which this sheet applies

==========

* Reference of the publication in which the datasets are reported:

Koster, E.H.W., Fang, L., Marchetti, I., Ebner-Priemer, U., Kirsch, P., Huffziger, S., & Kuehner, C. (2015). Examining the relation between mood and rumination in remitted depressed individuals: A dynamic systems analysis. *Clinical Psychological Science, 3,* 619-627. DOI: 10.1177/2167702615578129.

* Which datasets in that publication does this sheet apply to: All datasets reported in the article.

3. Information about the provided files

==========

3a. Raw data

---

* Have the raw data been stored by the main researcher?

[X] YES / [ ] NO

If NO, please justify: /

*On which platform are the raw data stored?

1. Raw data of questionnaires:

- [X] researcher PC: questionnaires (total scores)[Q_esm_2013.xlsx]
- [ ] research group file server
- [ ] other (specifiy)

2. Raw data of momentary assessment:

- [X] researcher PC: ESM data [esm_2013_O.sav]
- [ ] research group file server
- [X] other (specify): back-ups on external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

For 1 and 2:

- [X] main researcher
- [X] responsible ZAP
- [ ] other (specify): ...

3b. Other files

---

* Which other files have been stored?

- [X] files describing the step-by-step transition from raw data to reported results.

Specify: A detailed description can be found in the article

- [X] file(s) containing cleaned data?

Specify: A file containing the cleaned data has been provided for the ESM study [esm_2013_final.sav]

* On which platform are these other files stored?

- [X] researcher PC
- [ ] research group file server
- [X] other (specify): backup external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

4. Reproduction

==========

*Have the results been reproduced?:

[ ] YES / [X] NO

If YES, by whom (add if multiple): /

% Do daily dynamics in rumination and affect predict depressive symptoms and trait rumination? An experience sampling study

% Author: Lin Fang

% Date: 09/02/2017

1. Contact

==========

1a. Main researcher

- name: Lin Fang
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- e-mail: Lin.Fang@UGent.be

1b. Responsible ZAP

- name: Prof. dr. Ernst H. W. Koster
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Ernst.Koster@UGent.be

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2. Information about the datasets to which this sheet applies

==========

* Reference of the publication in which the datasets are reported:

Fang, L. (2017). Do daily dynamics in rumination and affect predict depressive symptoms and trait rumination? An experience sampling study. Chapter 6 in PhD dissertation.

* Which datasets in that publication does this sheet apply to: All datasets reported in the chapter.

3. Information about the provided files

==========

3a. Raw data

---

* Have the raw data been stored by the main researcher?

[X] YES / [ ] NO

If NO, please justify: /

*On which platform are the raw data stored?

1. Raw data of questionnaires:

- [X] researcher PC: questionnaires were assessed on paper, typed into an Excel-sheets [Q_esm_2015.xlsx]
- [ ] research group file server
- [X] other (specifiy): informed consent files on paper

2. Raw data of momentary assessment:

- [X] researcher PC: ESM data [esm_2015_O.sav]
- [ ] research group file server
- [X] other (specify): back-ups on external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

For 1 and 2:

- [X] main researcher
- [X] responsible ZAP
- [ ] other (specify): ...

3b. Other files

---

* Which other files have been stored?

- [X] files describing the step-by-step transition from raw data to reported results.

Specify: A detailed description can be found in the chapter

- [X] file(s) containing cleaned data?

Specify: A file containing the cleaned data has been provided for the ESM study [esm_2015_final.sav]

* On which platform are these other files stored?

- [X] researcher PC
- [ ] research group file server
- [X] other (specify): backup external hard drive

*Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [ ] all members of the research group
- [ ] all members of UGent
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4. Reproduction

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*Have the results been reproduced?:

[ ] YES / [X] NO

If YES, by whom (add if multiple): /

NEDERLANDSTALIGE SAMENVATTING

Ruminatie is van bijzonder belang voor onderzoekers gericht op kwetsbaarheid voor depressie. Volgens de *responsestyle theory* theorie wordt ruminatie opgevat als een vorm van reageren op negatieve stemming die zich op een voortdurende en repetitieve wijze richt op de gevolgen, oorzaken en betekenis van iemands gevoelens en problemen (Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Tientallen jaren van onderzoek hebben aangetoond dat ruminatie een van de belangrijkste risicofactoren is voor het ontstaan en de instandhouding van depressieve symptomen (Mor & Winquist, 2002; Nolen-Hoeksema et al., 2008). Twee belangrijke kwesties hebben veel aandacht gekregen in de afgelopen twee decennia. Ten eerste, welk type mensen de neiging hebben om vaker te rumineren dan anderen, en ten tweede, hoe mensen die rumineren vast komen te zitten in de vicieuze cirkel van dit rumineren. Verschillende theoretische kaders zijn voorgesteld en een grote hoeveelheid onderzoek is verricht met betrekking tot deze twee vragen (Joormann, 2010; Koster, De Lissnyder, Derakhshan, & De Raedt, 2011).

Whitmer en Gotlib (2013) hebben onlangs een *attentional scope* model van ruminatie ontwikkeld, in een poging om de aandachtsmechanismen bij ruminatie te begrijpen op een meer complete manier. Dit model stelt dat mensen met hoge ruminatiescores een vernauwde focus hebben van aandacht. Hoewel dit model een alternatieve verklaring biedt voor een groot aantal van de eerdere bevindingen in perceptie, werkgeheugen en het lange termijn geheugen, is er tot nu toe weinig onderzoek verricht dat dit model rechtstreeks toetst (Grol, Hertel, Koster, & De Raedt, 2015). Daarom is in een reeks van studies in dit proefschrift getracht om systematisch de belangrijkste hypotheses van dit model te onderzoeken.

Het belangrijkste doel van dit doctoraatsproject is om de onderliggende mechanismen van ruminatie en de impact ervan op de ontwikkeling van depressie te onderzoeken. In de eerste onderzoekslijn (hoofdstuk 2, 3 en 4) onderzoeken we rechtstreeks de voorspellingen van het attentional scope model van ruminatie dat individuele verschillen in aandachtsfocus invloed kan hebben op de neiging tot rumineren. In de tweede onderzoekslijn (hoofdstuk 5 en 6) onderzochten we de

dynamiek van de mechanismen van ruminatie in het dagelijks leven door de dynamische patronen in kortstondig ruminatief denken en affect te analyseren, die ons kunnen helpen om te begrijpen hoe rumineren zich ontwikkelt tot een maladaptieve gewoonte in het dagelijks leven. Hieronder vindt u de details van elk hoofdstuk samengevat.

In **hoofdstuk 2** testten we de voorspelling dat mensen met een hoog niveau van ruminatie een meer beperkte aandachtsfocus hebben. Dit zou niet enkel invloed hebben op de verwerking van negatieve informatie, maar ook op de verwerking van neutrale informatie als ze niet in een negatieve stemming zijn (Whitmer & Gotlib, 2013). Hoge en lage rumineerders werden geselecteerd na pre-screening op basis van hun ruminatie scores. Een goed gevalideerd *moving window* paradigma werd gebruikt om de aandachtsbreedte te meten, waarbij de oogbewegingen van de deelnemers geregistreerd werden (McConkie & Rayner, 1975). De deelnemers werden gevraagd zinnen te lezen en hun betekenis te verwerken. De positieve en negatieve stemming op baseline werden gemeten om te controleren voor de invloed van stemming op het aandachtsbreedte. Neutrale zelf- en andere gerelateerde zinnen werden als leesmateriaal gepresenteerd. De resultaten van deze studie toonden aan dat mensen in de groep met hoge scores op ruminatie als trek sneller lazen, wat bleek uit kortere totale tijd van het lezen, grotere leessnelheid, en minder aantal fixaties dan die in de groep met lage scores op de trek ruminatie in alle zelf- en andere gerelateerde zinnen in de conditie met een bepekt aandachtsvenster, die de moeilijkste leesconditie ten opzichte van het natuurlijk lezen was. De bevindingen suggereerden dat hoge rumineerders een smallere aandachtsfocus vertonen bij het verwerken van neutrale informatie na controle voor de positieve en negatieve stemming.

Omdat evenwel alleen neutrale zinnen als leesmateriaal werden geselecteerd in dit onderzoek, kunnen we deze bevindingen niet generaliseren voor alle soorten informatie. Daarom werd een tweede studie (**hoofdstuk 3**) uitgevoerd die de relatie tussen aandachtsbreedte en ruminatie bij verschillende valenties van informatie onderzocht. Hiervoor werden negatieve, neutrale en positieve zinnen opgenomen als leesmateriaal in hetzelfde moving window paradigma. Verschillende interessegebieden werden geselecteerd om nauwkeurig bijzonderheden omtrent de behandeling van emotionele en niet-emotionele woorden in elke zin te achterhalen. De resultaten van

een niet-geselecteerde sample met voldoende variatie in trek ruminatie toonde aan dat hoge rumineerders een smallere aandachtsfocus hebben bij het verwerken van zowel neutrale en emotionele informatie na correctie voor baseline gemoedstoestand. Interessant is dat in de tweede studie (hoofdstuk 3) de snellere totale leestijd van hoge rumineerders niet langer werd waargenomen bij het verwerken van negatieve informatie in de conditie met een kleine venstergrootte. Dit kan erop wijzen dat, hoewel gebruik makend van een gerichte aandacht in de verwerking van allerlei informatie, hoge rumineerders negatieve informatie nog steeds anders verwerken dan niet-negatieve informatie.

Om de causale relatie tussen ruminatie en aandachtsbreedte te testen, voerden we een training studie uit waarin het aandachtsbereik werd gemanipuleerd en het effect ervan op ruminatie werd onderzocht (**hoofdstuk 4**). We gebruikten een multiple-sessie training (5 dagen) in combinatie met een aangepaste versie van de Global-Local taak (Navon, 1977) en een visueel-ruimtelijke training taak (Fang et al., In press). De overdracht effecten van de training op aandachtsbereik werden onderzocht met een Global-Local evaluatietaak en een visueel-ruimtelijke aandachtsbereik evaluatietaak (Bosmans, Braet, Koster, & De Raedt, 2009; Grol et al, 2015.). Daarnaast werden de overdracht effecten van training op ruminatie getest wanneer de deelnemers geconfronteerd werden met een stressvolle situatie in het lab. Helaas werd slechts een vernauwingseffect waargenomen in de Global-Local assessment taak, terwijl er geen ander bewijs werd gevonden dat de training de de gewenste effecten teweeg bracht in de Global-Local evaluatietaak, noch in de visueel-ruimtelijke aandachtsbereik evaluatietaak. Als gevolg daarvan kunnen we geen sterke conclusies maken over het oorzakelijk verband tussen aandachtsbreedte en ruminatie.

Om de dynamiek van het dagelijkse ruminatief denken en stemming te ontdekken, voerden we een secundaire analyse (**hoofdstuk 5**) op een *experience sampling* studie, waarin depressieve patiënten en nooit-depressieve personen werden gevraagd om hun kortstondige ruminatie en stemming tien keer per dag gedurende twee opeenvolgende dagen te meten (Huffziger et al., 2013). Hun depressieve symptomen en trek ruminatie werden beoordeeld op baseline en op zes maanden follow-up. We gebruikten *entropie*, een maat voor de hoeveelheid voorspelbaarheid van informatie in een systeem (Shannon & Weaver, 1949), als de belangrijkste index

voor het weergeven van de dynamiek van het gehele systeem. De resultaten toonden aan dat een hogere entropie, wat een hoog gedesorganiseerd dynamisch patroon van ruminatief denken en stemming vertegenwoordigd, geassocieerd was met meer depressieve symptomen bij de follow-up van depressieve patiënten in remissie. Bovendien werd gevonden dat entropie ruminatie voorspelde bij follow-up in beide groepen.

We dienen op te merken dat de gezonde controlesubjecten in de vorige studie (hoofdstuk 5) streng werden geselecteerd als een vergelijkingsgroep voor de depressieve groep in remissie zodat ze relatief geringe depressieve symptomen vertoonden bij aanvang. Het is niet bekend hoe de dynamiek van ruminatief denken en stemming in het dagelijks leven geassocieerd is met toekomstige trek ruminatie en depressieve symptomen in de meer algemene populatie. Daarom werd een intensievere experience sampling studie uitgevoerd (**hoofdstuk 6**), waarin de deelnemers van een niet-geselecteerde sample met voldoende variatie in depressieve symptomen en trek ruminatie werden gevraagd om hun kortstondige ruminatief denken en affect acht keer per dag gedurende zeven dagen te beoordelen. Hun trek ruminatie en depressieve symptomen werden gemeten bij aanvang en bij zes weken follow-up. Entropie bleek trek ruminatie en depressieve symptomen te voorspellen bij de follow-up na correctie voor de baseline depressieve symptomen en trek ruminatie. In overeenstemming met onze vorige studie (hoofdstuk 5), waren hoge niveaus van entropie geassocieerd met een hoge mate van trek ruminatie en depressieve symptomen na zes weken. Cruciaal is dat entropie meer variantie van toekomstige depressieve symptomen en trek ruminatie kan verklaren dan het gemiddelde niveau van ruminatie tijdens de experience sampling metingen. Deze bevindingen zijn in overeenstemming met eerdere studies waaruit blijkt dat de structuur van een systeem zijn specifieke bijdrage heeft voor de voorspelling van psychopathologie (Hollenstein, Lichtwarck-Aschoff, & Potworowski, 2013).

Samengevat, aandachtsbreedte is één van de belangrijkste cognitieve factoren die samenhangen met de repetitieve aard van ruminatie. Het aandachtsbreedte model van ruminatie tracht de primaire bron van individuele verschillen te verklaren die ervoor zorgen dat sommige mensen meer rumineren dan anderen bij het ondervinden negatieve situaties. Het doel van dit project was om de verschillende predicties van dit

model te testen en het heeft verder bewijs voor de belangrijkste predicties geleverd. We hebben aangetoond dat individuen met hoge ruminatie trek een smallere focus van aandacht vertonen bij de verwerking van zowel neutrale en emotionele informatie wanneer ze niet in negatieve stemming zijn. Bovendien hebben onze bevindingen de toepassing van dit model uitgebreid naar de context van het dagelijkse leven. De instabiele en depressogene dynamische patronen van ruminatief denken en affect in de hoge trek rumineerders in onze experience sampling studie kunnen hun gebruik van een beperkte focus in aversieve of stresserende situaties weerspiegelen. Vanwege het beperkte succes van aandachtsbreedte manipulaties in onze multiple sessions training kunnen we geen conclusie over de causale richting tussen aandachtsbereik en ruminatie trekken. Ook blijft het onduidelijk hoe de dagelijkse dynamiek van hoge rumineerders exact veranderen na verstoringen, hetzij als gevolg van stressvolle gebeurtenissen of door psychotherapie. Toekomstige studies zijn nodig om het potentiële effect van aandachtsbreedte op ruminatie te onderzoeken, niet enkel via resultaten uit strenge laboratoriumexperimenten, maar ook via een meer ecologische evaluatie van kortstondige ruminatie en affect in steeds veranderende omgevingen. Dit kan ons helpen om een meer omvattend begrip te krijgen van hoe aandachtsbreedte interageert met ruminatie, en als zodanig inzicht bieden in de ontwikkeling van een betere behandeling en een preventieplan voor individuen hoog in trek ruminatie, gerelateerd aan een verhoogd risico op depressie.

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